AN EXPLORATORY STUDY OF THE
AIR FORCE'S TECHNICAL
IT INFRASTRUCTURE FLEXIBILITY

THESIS

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Abstract

The Air Force presently spends more than $4.9 billion annually on information technology (IT). However, the IT infrastructure has been identified as inappropriate for supporting the Air Force mission. To improve this situation the Air Force has identified infrastructure flexibility as key to future success. This led to the thesis question: What is the Air Force's current level of IT infrastructure flexibility?

This thesis looked at two constructs that indicate IT infrastructure flexibility—modularity and integration. A survey was sent to communication, computer, and information career field members to measure the degree of modularity and integration. Based on respondents' views, the Air Force's IT infrastructure does have some areas of flexibility, but other areas indicate very low flexibility. A primary concern is the flexibility of the Air Force's data and applications. Responses to both data flexibility and application flexibility survey questions consistently indicated low flexibility. The responses suggest the Air Force could achieve greater flexibility by turning its attention to database issues such as variety and adaptability of database protocols. Communications and platform flexibility are partially supported. Results indicate that reducing communication bottlenecks and fewer steps for accessing data from external end user locations could enable greater flexibility. Senior and junior IT leaders only diverged on one area of flexibility. Senior leaders had a higher rating on the number of entry points or interfaces available to external end users.

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I. Introduction

Problem

The Air Force spends more than $4.9 billion annually on information technology (IT). The dollars are spent developing an information infrastructure to process and transport information to Air Force, joint, and coalition users. Successful aerospace operations depend on this infrastructure to provide a capable and reliable IT capability (CONOPS for Air Force Information Enterprise, 2001). However, as former Secretary of the Air Force F. Whitten Peters said in May of 2000, "We have created an environment where our IT infrastructure is inappropriate for the work we are trying to do" (CONOPS for Air Force Information Enterprise, 2001:3).

In the 18 June 2001 version of the *CONOPS for Air Force Information Enterprise* several areas of weakness were identified in the IT infrastructure. Some of the areas identified were:

1. Inability to globally share resources
2. IT acquisition process is unable to keep pace with rapidly changing technology
3. Funding of stovepipe programs
4. Multiple transmission systems and architectures managed by different entities
5. Inadequate application and enforcement of standards
6. Too many standards

The CONOPS states, "To this end, a robust Air Force…must have a flexible and enforceable architecture." This illustrates the importance that flexibility has in the

operations of the Air Force's IT infrastructure. However, this researcher has not found any information or research on the Air Force's IT infrastructure flexibility. The goal of this exploratory research is to provide information in this area. Therefore, the following question is posed.

1. What is the Air Force's current perceived level of IT infrastructure flexibility?

At the very heart of this initiative toward achieving IT infrastructure flexibility is the concern that IT infrastructures have been anything but flexible in the past (Allen et al, 1991). Advances in processing speed (e.g. Moore's Law) and new software functionality keep IT support organizations in a constant state of change. Maintaining low costs while providing flexibility is also at the forefront of issues. Consequently, the challenge is to shift IT infrastructures from disablers to enablers of flexibility (Allen et al, 1991).

Current challenges to the Air Force's IT infrastructure, no less the Department of Defense's (DoD), are to integrate information into centrally managed assets that can be distributed across the IT enterprise (CONOPS for Air Force Information Enterprise). In the wake of the events of September 11, 2001, the Air Force's role in sharing intelligence information has been brought to the forefront in the battle against terrorism (Catterinicchea, 2001). The Air Force is also developing relationships with commercial and other government agencies to streamline operations that are reliant on information sharing. The goal is to have information systems (IS) that are flexible enough to communicate with the Air Force's internal infrastructure as well as to continue communicating with external organizations (CONOPS for Air Force Information

Enterprise; Catterinicchea, 2001). Creating this flexibility is a goal of the Air Force (Air Force Vision 2020).

An advantage of having a flexible IT infrastructure is that it allows some shift in focus from the technical IT issues to the information issues. Take for instance the Air Force's initiative toward developing an information enterprise or "infostructure" (One Air Force…One Network). Once this infostructure is created and managed, then information utilization can presumably be optimized for the benefit of operations throughout the Air Force. However, the Air Force has different areas of responsibilities (i.e. MAJCOMs) with independent budgets and an ability to buy and utilize different technologies and standards (CONOPS for Air Force Information Enterprise). Without the standards and flexibility of a common IT infrastructure to withstand such independence, the infrastructure may quickly become inflexible and unable to support its purposes.

Duncan (1995) and Byrd et al (2000) have developed instruments for measuring infrastructure flexibility (platform compatibility, network connectivity, application modularity, and data modularity). This research will measure the flexibility of the Air Force infrastructure using these instruments. It is intended that this research will provide a picture of IT infrastructure flexibility. This will help IT infrastructure planners and architects develop the needed Air Force IT infrastructure.

IT infrastructure flexibility has been described as a highly sought characteristic of an organization's infrastructure enabling system developers to adapt systems to do things that were not designed or developed from the onset (Duncan, 1995). Although much research has pursued infrastructure flexibility, it is still a quality being sought by both

practitioners and academics. In a Society for Information Management (SIM) Delphi study the most important issue identified by IT executives was building and developing a flexible IT infrastructure (Brancheau et al, 1997). Additionally, flexible infrastructures enable strategic advantages (Duncan, 1995). "One firm's infrastructure may make strategic innovations in business processes feasible, while the characteristics of competitors' infrastructure may likewise prevent their ability to imitate the innovations rapidly enough to mitigate the first mover's advantage" (Duncan, 1995:38).

Flexible infrastructures have an adversary, namely inflexibility. Inflexibility results in the difficulties experienced when users are unable to modify systems to accommodate new requirements that are suddenly thrust upon them (Duncan, 1995). The primary reason for these difficulties is because systems were not originally developed to handle novel needs of users (Duncan, 1995), nor were they designed to work together. In the past developers either implemented dramatic modifications to systems or installed new systems (Duncan, 1995). Another approach is to design and build IT infrastructures that are flexible enough to enable novel uses for mission, tactical, strategic and business needs (Duncan, 1995). This research intends to provide a basis for exploring this alternate approach by providing the Air Force a better understanding of its IT infrastructure flexibility.

Approach

The next chapter explores the background associated with infrastructure flexibility. This includes an academic literature review as well as identifying the Air Force's IT infrastructure. An IT infrastructure flexibility survey is also presented for

measuring the views of IT professionals. The third chapter in this study outlines the methodology for applying this survey to the Air Force. The fourth chapter analyzes and presents results from the survey. The fifth chapter provides a discussion of findings, the recommendations, limitations, and areas for future research.

II. Literature Review

Outline

This chapter consists of two parts that establish the background for analyzing the Air Force's IT infrastructure flexibility. The first part focuses on the Air Force and an overview of its current unclassified IT infrastructure. This study is limited to the unclassified infrastructure only. Further research at a later time may be needed to address the classified infrastructures. The second part of this chapter focuses on academic research and studies associated with IT infrastructure flexibility. The academic research includes definitions, constructs, and related topics. An instrument used to measure IT infrastructure flexibility is also presented. The instrument measures IT infrastructure flexibility by evaluating two constructs: modularity and integration. Modularity indicates the flexibility of data and applications (Byrd et al, 2000; Duncan, 1995). The second construct is integration. Integration measures the flexibility of computer platforms and networks/telecommunications (Byrd et al, 2000). Exploring these constructs provides an understanding of what affects flexibility. The concluding part of this chapter presents these constructs as a model. This model will be used for measuring the Air Force's infrastructure flexibility.

Air Force IT Infrastructure

The purpose of this section is to develop an understanding and baseline of the Air Force's IT infrastructure. Researching the characteristics of the Air Force's IT infrastructure may help build the background necessary for understanding why one part

of the IT infrastructure may be flexible and another part inflexible. This section starts out by providing an overview of the architectural guidance set by the DoD and Air Force and then covers the Air Force's major enterprise systems and networks. Within the overview of enterprise systems and networks, different types of information are addressed as well as the Air Force missions that utilize the IT infrastructure.

Air Force IT Guidance Overview

The overarching guidance set forth by the DoD and followed by America's armed forces is Joint Vision 2020. Within Joint Vision 2020 IT infrastructures are addressed to provide information technology interoperability between the departments of the DoD, as well as other government departments, agencies, and foreign entities. Another force in the Air Force's IT infrastructure is the Clinger/Cohen Act, also known as the Information Technology Management Reform Act of 1996 (ITMRA). The Clinger/Cohen Act mandates who is responsible and how to report on information resource management throughout the federal government. An amendment to the Clinger/Cohen Act in 1998 mandates interoperability of IT in the Department of Defense. This section covers these and other guidance and subordinate documents that address the Air Force IT infrastructure. Subordinate documents include the Joint Technical Architecture (JTA), the Air Force Joint Technical Architecture (AF-JTA), the Global Information Grid Architecture Management Plan (GRID), and the CONOPS for Air Force Information Enterprise.

Joint Vision 2020

Joint Vision 2020 provides the strategic vision for being prepared for the unknown challenges that lay ahead in defense of the United States. Within this

document, information superiority and the importance of the IT infrastructure are outlined. Joint Vision 2020 is important to this research because it provides guidance to develop flexible infrastructures. Joint Vision 2020 states, "The joint force of 2020 will use superior information and knowledge to achieve decision superiority…the breadth and pace of this evolution demands flexibility." From this direction the Air Force has further defined it's role within information superiority and flexibility. The Air Force Vision 2020 states, "Fast, flexible, responsive, reliable, support will be the foundation of all Air Force operations." Achieving this spectrum of dominance requires enhanced flexibility (Information Superiority, 2001). Thus, the vision for the future of the Air Force and DoD is enhancing flexibility. This is also the goal of this study, specifically towards a better understanding of Air Force's level of infrastructure flexibility.

Clinger/Cohen Act

The Clinger/Cohen Act mandates the responsibility of information resource management, including acquisitions of information resources to Chief Information Officers (CIOs). CIOs are required to lead information resource management at Federal Government departments and agencies. The Clinger/Cohen Act provides the guidance set forth for information resources management. Information resources mean "information and related resources, such as personnel, equipment, funds, and information technology" (The Paperwork Reduction Act of 1995). Thus, the management of IT infrastructures is included. A possible shortfall of the Clinger/Cohen Act with the flexibility of the Air Force's IT infrastructure is the importance placed on acquisition and monetary savings on information resource management. This is similar to Allen et al's (1991) article on the tradeoffs between efficiency and flexibility, where efficiency has

been a long-standing concern of organizations and that flexibility is still an emerging issue. Since this act mandates the management of information and the main focus is on cost controls, performance of IT infrastructures may be lessened in place of greater monetary savings. An amendment to the Clinger/Cohen Act (Public Law 105-261) extends the responsibilities of CIO's. The amendment mandates interoperable information technology and national security systems. However, unlike costs that can be supported, reporting on interoperability is a much more subjective goal. A means of measurement for interoperability could help. This study could provide a piece of that information through the degree of flexibility.

Joint Technical Architecture (JTA)

The Air Force's IT infrastructure vision is guided through Joint Vision 2020 and Air Force Vision 2020, but the technical guidance comes from the Joint Technical Architecture (JTA). This document provides the essential standards and glue that enable the different pieces of the infrastructure to interoperate. "The JTA provides DoD systems with the basis for the needed seamless interoperability. The JTA defines the services areas, interfaces, and standards (JTA elements) applicable to all DoD systems, and its adoption is mandated for the management, development, and acquisition of new or improved systems throughout DoD" (JTA, Version 3.1:3). The JTA covers different domains within the DoD. The importance of covering these domains is they define what the IT infrastructure operationally supports and provides a more in-depth understanding of the IT infrastructure. The domains that characterize the JTA are as follows:

1. Command, Control, Communications, Computers, Intelligence, Satellites, and Reconnaissance (C4ISR)
2. Combat support (CS)
3. Modeling and Simulation (M&S)
4. Weapon Systems

    (JTA, Version 3.1)

Within these groupings are additional domains or sub-domains, which stratify the architecture into specific areas of support. The following domains can be seen below with their sub-domains:

1. Command, Control, Communications, Computers, Intelligence, Satellites, and Reconnaissance (C4ISR)
    a. Cryptological
    b. Nuclear Command and Control
    c. Space Reconnaissance
2. Combat support (CS)
    a. Automated Test Systems
    b. Defense Transportation System
    c. Medical
3. Modeling and Simulation (M&S)
4. Weapon Systems
    a. Aviation
    b. Ground Vehicles
    c. Missile Defense
    d. Missile Systems
    e. Munitions Systems
    f. Soldier Systems

    (JTA, Version 3.1)

Two additional important concepts within the DoD and the Air Force that are covered within the JTA are the Technical Reference Model (TRM) and the Defense Information Infrastructure Common Operating Environment (DII COE). The TRM has been adopted by the JTA as a framework that presents the JTA standards (Joint Technical Architecture, Version 3.1). The TRM ensures consistency between the services,

domains, interfaces, and other elements for defining the architectural and designing components (Joint Technical Architecture). The TRM was chosen as the framework for presenting JTA-mandated standards because of the "model's inherent support of open-systems concepts" (Joint Technical Architecture). The TRM model addresses the application software entity, the application platform entity, an external environment, and interfaces that consist of application program interfaces (API) and external environmental interfaces (EEI) (Joint Technical Architecture). The importance of this model is that the TRM is an architectural model the Air Force is mandated to use.

DII COE is another mandated architecture, but one that is not fully compliant with JTA standards (Joint Technical Architecture). DII COE is a mandated information infrastructure for all Command and Control (C2), Combat Support, and Intelligence Systems supporting the Joint Task Forces (JTFs) and Combatant Commands (Joint Technical Architecture). All applications that are integrated into a DII COE environment must comply with a DII COE Level 5 compliance, which requires the software to be segmented, a DII COE Kernel, and installed with COE tools (Joint Technical Architecture). DII COE standards are not fully compliant with JTA standards (Joint Technical Architecture). "However, the goal of the COE effort is to evolve to be fully compliant with the applicable JTA standards" (Joint Technical Architecture). The conflicting standards of DII COE and JTA show one example of where flexibility may be hampered by the constrictiveness of using all the standards from either DII COE or JTA, or may provide flexibility by enabling a choice between these two architectures. However, the conflict between these architectures supports a deeper look into the Air

Force's IT infrastructure and provides a better understanding of how these standards may affect flexibility.

Global Information Grid Architecture (GIG)

An effort to further define the Air Forces architecture can be found in the Global Information Grid Architecture (GIG). GIG is "a globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policy makers, and support personnel" (DoD CIO Guidance and Policy Memorandum No. 11-8450). GIG uses the JTA as a basis for the technical view (GIG Architecture). An important aspect of the GIG is its influence by the Defense Planning Guidance (DPG) and Program Objective Memorandum (POM) (GIG Architecture). These programs provide the strategic direction for the Air Force mission and the money to control that direction. This direct supply of money and strategy to support the Air Force is vital to shaping the Air Force's IT infrastructure. Additionally, this document provides insight into a future view of how the IT infrastructure may look. The specific objectives of the GIG Architecture follow:

- Develop a single, integrated operational view for the GIG Architecture, using the Joint Operational Architecture (JOA) as the core
- Expand the GIG
- Architecture focus to other Commander-in-Chiefs (CINCs), Services, Agencies, and Joint Mission Areas (JMAs)
- Incorporate specified extant architectures using automated means to the maximum extent possible.
- Set a minimum of 3 levels of decomposition as a goal
- Influence the current Defense Planning Guidance (DPG) and Program Objective Memoranda (POM)

- Promote the development of enterprise, mission, and functional architectures that comprise the GIG Architecture throughout the DoD and the IC, with particular emphasis on CINCs, Services, and Agencies

CONOPS for Air Force Information Enterprise

Another defining document for the Air Force's IT infrastructure is the Concept of Operations (CONOPS) for Air Force Information Enterprise. This document provides the current state of the Air Force's IT environment as well as the desired end states. The current environment is listed below with a focus of the areas needing improvement.

1. No centralized authority for implementing Air Force IT or empowerment to operate the Air Force Information Enterprise day-to-day.
2. Inadequate applications and enforcement of standards
3. Implementation of non-interoperable standards for a particular functionality results in system being non-interoperable even though they comply apparently applicable standards.
4. Funding of stovepipe programs
5. Multiple transmission systems and architectures managed by different entities
6. Duplication of IT processes and capabilities
7. Inability to globally share resources
8. Inadequate bandwidth across the enterprise—fixed and deployed
9. Inefficient resourcing of technologies that provide reliability and availability
10. Lack of information assurance mechanisms, technology and policy to securely communicate freely across Air Force, allied, and coalition enterprises.
11. IT acquisition process is unable to keep pace with rapidly changing technology
12. Inadequate IT training programs which should provide the foundation for IT use/implementation
13. Limited integration/linkage of MAJCOM IT systems to the Air Force Enterprise model
14. IT career field too broad to ensure airmen become experienced IT professionals/managers; poorly defined career path for IT airmen
15. Insufficient number of qualified IT personnel for the assigned tasks, and difficulties in retaining IT professionals
16. Air Force IT policy lags technology availability
17. Lack of criteria requiring total force inclusion in software programs and processes

18. Lack of information life cycle support necessary to protect the integrity of information within systems
19. An effective method for life cycle management of information
    (CONOPS for Air Force Information Enterprise)

This list provides an orientation of where the Air Force stands on IT infrastructure improvement. The CONOPS also provides the end states, or where the Air Force plans on being. Among these strategies is one pursuing an enterprise approach (CONOPS for Air Force Information Enterprise). Within the enterprise approach one requirement is flexibility. Thus, an end state is having a flexible enterprise or in the context of this study…a flexible IT infrastructure. However, the CONOPS for Air Force Information Enterprise has no direct reference to what level of flexibility is currently held. The CONOPS has developed a list of the current environment as discussed above, but desires a state of flexibility without providing the current state of flexibility. This study proposes to provide that next step in research…to provide the level of IT infrastructure flexibility and factors surrounding this construct.

Air Force Systems and IT Infrastructure Components

The Air Force's IT systems and infrastructure components are guided by the JTA and its subordinate documents that provide an integration of strategy and standards toward information superiority. The major enterprise systems that characterize the Air Force's IT infrastructure are the Global Command and Control System (GCCS), the Global Combat Support System (GCSS), Air Force Portal, and many functional systems such as Core Automated Maintenance System (CAMS), Standard Base Supply System (SBSS), Cargo Movement Operations Systems (CMOS), Air Force Equipment Management System (AFEMS), and Weapon System Management Information System

(WSMIS). In addition to these systems, desktop applications such as the Microsoft suite of office programs are used throughout the Air Force. The purpose of this section is to cover these major systems and applications used throughout the Air Force and further develop a picture of the current IT infrastructure. This picture provides the applications and systems.

Air Force Portal

The Air Force Portal or enterprise portal is a "a dynamic, single, web-enabled access point that provides Air Force users a window into information, applications, and processes that are globally available for an Expeditionary Aerospace Force" (HQ SSG, 10 Aug 2000). The portal framework of the Air Force Portal "provides a robust search capability across structured and unstructured repositories, taxonomy support, content management/aggregation, personalization, and application integration/development" (HQ SSG, 10 Aug 2000). The vision for the developing Air Force portal is to provide:

1. Worldwide window into a complete set of integrated, web-enabled applications.
2. Secure, browser-based, platform-independent access, anytime, anywhere
3. Single sign on
4. Tailor-able based on user identify/role
5. Smart push and pull of information
6. Tiered system administration and content management
   (Ibid)

Functions that are currently planned for the Air Force Portal are (1) Air Force white pages (based on personnel and e-mail directories), (2) syndicated content such as early bird, weather, CNN, local news, and base news, (3) interface with legacy applications such as CAMS, SBSS, CMOS, WSMIS, SCS, and AFEMS, (4) Self serve applications such as links to Air Force publication and forms, computer based training, and military

personnel flight, and (5) Air Force and public web searches. Many of these functions already have accessibility over the Internet, but the Portal will allow a central location for access.

The Air Force Portal is also designed to integration with the Global Combat Support System Air Force (GCSS-AF). The Air Force Portal is acting as the presentation layer of GCSS-AF (Air Force Portal Management Guide). The goal of GCSS-AF is to modernize base level support systems (Seacord, 2000). Integrating GCCS-AF with the Air Force Portal enables an infusion of web technology. The mission areas that are supported by GCSS-AF are logistics, finance, personnel, medical, business information and functional systems (Seacord, 2000). The GCSS-AF is also part of a bigger portal consisting of all the Branches in the Department of Defense (DoD), and is called Global Combat Support System (GCSS).

Global Command and Control System (GCCS)

The Global Command and Control System (GCCS), as opposed to the Global Combat Support Systems (GCSS), provides a command and control system for Air Force commanders as well as commanders in other braches of the DoD (GCCS, March 2001). This system supports a vital aspect of the Air Force's mission by providing a near real-time picture of the battlespace (GCCS, March 2001). The architecture of GCCS is directed by DII COE. Since DII COE is not fully compliant with Joint Technical Architecture (Joint Technical Architecture), the primary command and control systems used by the DoD and the Air Force may have problems interoperating with logistical, maintenance, and other supporting systems in order to carry out the Air Forces missions.

Defense Messaging System (DMS)

The Defense Messaging Systems (DMS) is designed for sending messages through electronic mail. The intended use is to provide worldwide access to all strategic and tactical users in the DoD as well as other authorized entities such as U.S. Government, Allies, and Defense Contractors (Defense Message System Product Plan). The security requirements of DMS mandate a use of writer-to-reader messaging system (Defense Message System Product Plan). The implementation of this requirement is the FORTEZZA card placed on the sending and receiving computers. DMS is a replacement system for the older AUTODIN messaging systems. Similar to GCCS, DMS is also built on the architectural foundations of DII-COE (Defense Message System Product Plan), and thus inherits the potential problems with interoperating with other JTA mandated standards.

Defense Information Systems Network (DISN)

The Defense Information Systems Network (DISN) is the end-to-end global network for information transfer in the DoD (DISN Architecture). The DISN architecture includes use of military satellite communications (MILSATCOM), commercial satellite communications, leased telecommunications services, dedicated DoD Service and Defense Agency network, and mobile/deployable networks (DISN Architecture). Although the Defense Information Systems Agency (DISA) is responsible for DISN, the Air Force is interconnected via satellites and Air Force operated and leased networks. The Air Force is reliant on DISN for its long haul connectivity, and thus, DISN is an important part of the Air Force's IT infrastructure.

Platforms, Applications, and Data

The platforms, applications, and data used in the Air Force are as varied and large as any government department or commercial company. Although standards are followed through the Joint Technical Architecture, DII COE, and subordinating documents as discussed earlier, many choices between vendors are available. Commercial-off-the-shelf (COTS) as well as in-house developed products and government-off-the-shelf (GOTS) products are utilized for applications. Platforms such as Sun Microsystems, Dell, Micron, Compaq, Silicon Graphics, McIntosh, IBM and many others are used. Data used in the Air Force is also varying in types and formats. Many standards are in place such as the DoD Data Dictionary, digital maps created by the National Imagery and Mapping Agency (NIMA), commercial data standards, and JTA standards as well as localized standards amongst many others. The multitude of standards has been identified as a problem by the Air Force (CONOPS for Air Force Information Enterprise). Overly comprehensive standards have also been recognized as a limiting factor of infrastructure flexibility in academic studies (Kayworth et al, 2000).

Air Force IT Infrastructure Summary

The Air Force's unclassified IT infrastructure has many documents guiding its future. Technical guidance can be seen in the Joint Technical Architecture (JTA), Air Force Joint Technical Architecture (AF-JTA), the Defense Information Infrastructure – Common Operating Environment (DII-COE), and many others. Documents such as the Clinger/Cohen Act provide guidance on who is responsible for managing the information resources. Together these documents provide support for a

common goal in defense of the United States. This vision can be seen in Joint Vision 2020. Future performance and success in Air Force operations rely on these documents. Without enterprise-wide guidance, independent actions result in inefficient management of resources (Kayworth et al, 2000). This study focuses on the flexibility of the Air Force's technical IT infrastructure. However, much of the results might be directly affected by the guidance set forth by these documents.

Academic Literature

The final section in this chapter covers academic research associated with IT infrastructure flexibility. IT infrastructures and IT infrastructure flexibility have generated much interest within the private sector as it has evolved into a central issue for competing firms (Duncan, 1995). This importance has caught the attention of academic researchers (Byrd et al, 2000; Duncan, 1995), and they have pursued a better understanding of the highly valued flexible IT infrastructure (Byrd et al, 2000). This section covers definitions, constructs, and designs behind these studies. Other topics include trade-offs between flexibility and standardization. The aim is to find an optimal environment for IT infrastructure performance. In addition, this section describes scenarios of being too flexible or too standardized and rigid. Exploring the varying degrees of flexibility and inflexibility provides this study the background in basic relationships required to explore the Air Force's IT infrastructure flexibility.

Research has provided a definition for IT infrastructure that consists of two related, but distinct elements (Byrd et al, 2000). The two elements are the technical IT infrastructure and the human IT infrastructure (Broadbent et al, 1997; Broadbent et al,

1996; Henderson et al, 1994; Byrd et al, 2000). "The technical IT infrastructure is oftentimes what is being alluded to when practitioners and researchers discuss IT infrastructure" (Byrd et al, 2000). The technical infrastructure has also been called the enabling foundation of IT capabilities that are shared and represents the foundation for which an organization depends (McKay et al, 1989; Byrd et al, 2000). Another definition is the organization's information resource capacity intended for sharing (Davenport et al, 1994; Byrd et al, 2000). The technical IT infrastructure is an organization's institutionalized IT practice and the consistent foundation on which the specific business activities and computer applications are built (Davenport et al, 1994; Byrd et al, 2000). Yet another definition of the technical infrastructure is the "set of shared, tangible IT resources forming a foundation for business applications" (Byrd et al, 2000:169). Earl (1989) identified the components of the technical infrastructure as computing, communications, data, and applications. Duncan (1995) also identified the same structure, but labeled the components: platform technology, network and telecommunications technologies, data, and core software applications.

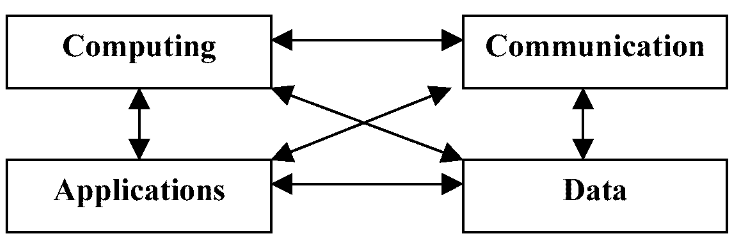


Figure 1: Infrastructure Components (Earl, 1989)

The other element of the IT infrastructure is the human IT infrastructure. "The human IT infrastructure includes human and organizational skills, expertise,

competencies, knowledge, commitments, values, norms, and organizational structures" (Byrd et al, 2000:169). The human aspect of flexible infrastructures can be explained by the phenomenon that if infrastructures are expected to be flexible and provide functionality not originally designed for, someone must be able to accomplish these modifications when necessary. Without people, who enables an infrastructure to adapt? Todd et al (1995) reported that more in-depth technical skills in more areas were desirable. Henderson et al (1993) suggested that business functional knowledge and skills contribute to infrastructure flexibility by affecting the IT organization's ability to plan effectively.

This study focuses on the technical IT infrastructure, but an understanding of the human IT infrastructure may become invaluable as a source to enable a holistic understanding of IT infrastructures. Additionally, the technical instances in an IT infrastructure are directly related to the people implementing and maintaining the technical infrastructure. In order for the technical infrastructure to be flexible, people need to be flexible, enabling the unplanned changes required for IT infrastructure flexibility. "This necessitates a new type of adaptable employee who can easily handle IT coordination and boundary issues" (Byrd et al, 2000:171).

IT Infrastructure Flexibility

The previous section covered the definitions of IT infrastructure and some of the research relating to the types of IT infrastructures. Keeping the IT infrastructure in mind, this section focuses on technical IT infrastructure flexibility. A definition of IT infrastructure flexibility is the "ability to easily and readily diffuse or support a wide

variety of hardware, software, communications technologies, data, and core applications" (Byrd et al, 2000:172). The variety includes more than just supporting the different hardware brands and application products. It must be flexible enough to handle changes within these different brands and products without causing major changes across the IT infrastructure. Although being able to support a wide variety of products and functionality is at the very center of flexibility, there is a cost. "The history of computing in many large corporations is filled with expensive and painful failure, especially with attempts to build common systems and central data stores" (Allen et al, 1991:441).

Efficiency and Flexibility

According to Allen et al (1991) the two most important attributes in an IT infrastructure are efficiency and flexibility. Efficiency or keeping costs low have always been a priority for organizations. However, flexibility is emerging as the critical IT infrastructure issue of the future (Allen et al, 1991). Flexibility provides the rapid response to changing conditions. But, flexibility is costly. Flexible technologies are often more advanced and costly than lesser traditional technologies (Duimering et al, 1993). A balance is needed for keeping costs low while having the flexibility to provide rapid response for mission needs. "Combining both is the challenge faced by many organizations…because competitive requirements increasingly call for not just efficiency and economy or speed and flexibility, but both simultaneously" (Allen et al, 1991:444). Additionally, there is no combination of efficiency and flexibility that is ideal for every organization. Thus, each IT infrastructure must be managed to optimize this balance. Supplying information on the Air Force's IT infrastructure flexibility is a goal of this

study. Hopefully, this information will be able to help the Air Force in achieving that balance.

Compatibility, Connectivity, and Modularity

An important finding in the study of IT infrastructure flexibility has been the constructs found to measure IT infrastructure flexibility. Duncan's (1995) study produced the first IT infrastructure flexibility constructs. The constructs produced by Duncan are compatibility, connectivity, and modularity. The three qualities can be seen below positioned in the corresponding components of the infrastructure for which they apply. The components of the infrastructures are platform, network/telecom, data, and application (Earl, 1989; Duncan, 1995; Byrd et al, 2000).

Table 1: Infrastructure Flexibility Qualities (Duncan et al, 1995)

Components	Flexibility Qualities
Platform	Compatibility
Network/Telecom	Connectivity
Data	Modularity
Application	Modularity

The first flexibility quality is "compatibility" and is shown here to be a measure of platform flexibility. The platform consists of hardware used for processing information and the operating system associated with the hardware (Earl, 1989). "Compatibility is the ability to share any type of information across any technology component" (Byrd et al, 2000:171). The level of compatibility is directly associated with data sharing. Sharing simple messages consisting of text is a simple example of compatibility, while at a more complex level any form of data can be exchanged such as voice, video, text, image, audio, or some combination (Byrd et al, 2000). Additionally,

information should still be able to be shared despite any differences in the manufacture, make, or model of the platform.

The second flexibility quality is "connectivity", which is used as the measure for network/telecom flexibility. "Connectivity is the ability of any technology component to attach to any of the other components inside and outside the organizational environment" (Byrd et al, 2000:171). Connectivity has also been described as reach. Keen (1991:179) describes reach, as "the locations to which a platform is capable of linking." Ultimately, the goal is to be able to connect to any person, anywhere, similar to the telephone system's reach around the world today. Reach and connectivity are qualities of the network/telecom components, which are defined as "the telecommunications networks and their associated mechanisms for interlinking and interworking" (Earl, 1989:95).

The third flexibility quality is "modularity", which is the measure for data flexibility and application functionality. The general description of modularity is the ability to insert or replace any component in a structure such as software, hardware, and data easily and without any major overall effect on the rest of the infrastructure (Byrd et al, 2000). Some examples of applications are word processors, web browsers, database programs, etc. (Earl, 1989). Application modularity is identifying individual processes or functions and then isolating each of those processes into standardized individual modules (Duncan, 1995). At a very basic level, routine data calls are modularized and are used over and over again as requested (Duncan, 1995). A more advanced use of application modularity may store business rules and functions separately from the main body of applications. According to Byrd et al (2000:171) "modularity also relates to the degree to which IT software, hardware, and data can be either seamlessly or effortlessly

diffused into the infrastructure or easily supported by the infrastructure." Additionally, when applications become more modular and encapsulated the application's code and business rules that have also been encapsulated become much more accessible (Duncan, 1995). A disadvantage of modularity is that "in order for one object to interact with another (via procedure call) it must know the identity of that other object" (Garlan et al, 1994:9). This is in contrast to other systems that do not need to know the identity for interaction and are thus processed more efficiently (Garlan et al, 1994).

"Data flexibility" is measured by the modularity construct. Data is a discrete grouping of objective facts that surround some event or entity (Davenport et al, 2000). Data is important to organizations because it is the essential unit for the creation of information (Davenport et al, 2000). Modularity pertains to data in a very similar way to application modularity (Duncan, 1995) because they both follow the same modularity principles discussed later in this chapter. Each organization's use of data in topics such as data ownership and approach to data or information architectures has an impact on the sharability of data and it's reusability (Duncan, 1995). Data is considered flexible when modifications to the data are not necessary when applications or other system adjustments are made. "The extent to which data and data management technology do not need to be changed when radical changes in processes or technology or systems occur may reflect the true flexibility of this part of the infrastructure" (Duncan, 1995:49).

Sharing and Reuse

Another important finding about IT infrastructure flexibility is the importance placed on developing knowledge about sharing and reuse. Duncan contends that organizations must base their knowledge on infrastructure flexibility as to what degree

the infrastructure resources can be shared and reused. This study pursues that goal of providing knowledge on sharing and reuse. This study focuses on measuring the Air Force's IT infrastructure flexibility, and in doing so also analyzes the sharing and reuse. Thus, results from this study can be provided to the Air Force as a means of knowledge toward achieving flexible infrastructures.

Other research on sharing and reuse has maintained that sharing should be the goal of information systems (IS) departments (Keen, 1991). Sharing should be focused toward gaining economies of scale and combining information from fragmented organizations within a company or possibly between companies. This sharing also creates new ideas leading to new products and services while at the same time avoiding duplication of assets and efforts. Additionally, information flows become cross-functional and can even bridge sharing between customers and suppliers (Keen, 1999). Sharing across the organization relies on communication and information sharing. Achieving these objectives requires compatibility throughout the infrastructure components. These components include the platforms, applications, networks, and data (Keen, 1991). Additionally, integration of separate components is also required (Keen, 1991). Similar to infrastructure flexibility, the organization needs compatible, connected, and modular IT infrastructures toward achieving their goal. Accomplishing this goal is not done by creating some single massive infrastructure, but by the creation of common standards (Keen, 1991).

Unlike the sharing construct, reusability has not been as well researched, but it is just as essential to infrastructure flexibility (Duncan, 1995). Reusability is where a module consisting of either software or data is designed so that it can be used over and

over again throughout the infrastructure. The module can also be interchanged with other modules so that little to zero system modification is required (Hoffer et al, 1999). "Reusability is key to our understanding of applications and data as elements of infrastructure" (Duncan, 1995:42).

> In a private interview, an IS architecture executive at a firm viewed by its competitors as a leader in both IT achievement and vision offered a third explanation of the role of data and applications in IT infrastructure. Data and software components are subsumed into infrastructure as they become technically independent—standardized, sharable, and reusable in a variety of business implementations, present, future planned, and future unknown. (Duncan, 1995:43)

Reusability is represented in modular concepts of application development and object oriented database design. A term has been given toward designing reusable resource, namely modularity. IS elements such as data and software that are repeatedly used should be converted into objects that are reusable and therefore modular (Duncan, 1995). While standards provide infrastructure components to be shared and reused, overly strict standards can minimize the business options available for situational advantages. This results in falling short of optimal competitiveness and productivity (Duncan, 1995).

Integration and Modularity

Another study with similar results and constructs to Duncan's for evaluating infrastructure flexibility is Byrd et al's (2000) "Measuring the Flexibility of Information Technology: Exploratory Analysis of a Construct." Within this study an instrument was developed and validated to measure IT infrastructure flexibility. This instrument will be used for the measurement of IT infrastructure flexibility of the Air Force.

Within Byrd et al's (2000) research into developing an instrument for measuring IT infrastructure flexibility two primary constructs were identified: 1) integration and 2) modularity. These findings are very similar to the constructs already covered in Duncan's (1995) research. The similar findings between these two studies reinforce the appropriateness of using these constructs in this study. They provide a foundation for this study's goal of measuring and analyzing the Air Force's IT infrastructure flexibility.

The similarities between Byrd et al's findings and Duncan's can be seen by both parties use of the modularity construct. Duncan (1995) used modularity for both the data and application components. Byrd et al (2000) also used the modularity construct in a similar fashion, but described the application and data components as application functionality and data transparency and then summarized both constructs as modularity. The second similarity between their researches is on the platform and network/telecom components of the infrastructure. Duncan used compatibility for the platform component and connectivity for the network/telecom component. Byrd et al used integration as one construct encapsulating both IT compatibility and IT connectivity. Thus, the two findings are virtually identical in the constructs for measuring infrastructure flexibility. The table below depicts the infrastructure flexibility constructs of Duncan and Byrd et al.

Table 2: Flexibility Constructs

Components	Duncan's Flexibility Qualities	Byrd et al's Factors
Platform:	Compatibility	Integration
Network/Telecom:	Connectivity	Integration
Data:	Modularity	Modularity
Applications:	Modularity	Modularity

Integration Construct

Integration in this study is an indicator of platform and network/telecommunications flexibility. According to Byrd et al (2000), integration resulted from a need for platform transparency. Research respondents considered transparent access into all the organizational platforms the indicator for flexibility. Thus, the first requirement is that platforms are compatible (Byrd et al, 2000). The second requirement is that networks and telecommunications provide connectivity (Byrd et al, 2000). Integrating these two qualities of platform compatibility and network/telecommunications connectivity provide a transparent and integrated environment. Characteristics of integration include common standards, information sharing, coordination, and collaboration (Alter, 1999). "Integration is the mutual responsiveness and collaboration between distinct activities or processes. In general, the extent of integration between two processes or activities is related to the speed with which one responds to events in the other" (Alter, 1999:6). Byrd et al states, "It is not difficult to see why these two dimensions could ultimately be merged in a more parsimonious model as one factor. Modern telecommunications technologies can typically support the transmission and distribution of all types of information, including voice, image, and video."

An important aspect of the integration construct is the essential role that standards play. Integration is reliant on standards because highly comprehensive standards are considered to enable increased cooperation amongst enterprise-wide integration needs (Kayworth et al, 2000). Keen (1991:186) states "standards are key to integration." Standards allow a greater level of detail and guidelines that facilitates a coordinated effort

for IS departments (Kayworth et al, 2000). When standards become vital guides in IS operations and provide compatibility throughout an infrastructure, managers are likely prepared for the integration complexities involved with enterprise wide infrastructures. Additionally, "IT infrastructure standards serve a valuable role in facilitating a balance between attention to localized and enterprise-wide integration of the IT infrastructure" (Kayworth et al, 2000:55). Without standards, and their coordinating effect, autonomous decisions of local units could impede the required integration needed for the enterprise to fully exchange information and provide interoperability.

Modularity Construct

Modularity supports data and application flexibility. The reason applications and data are grouped together in one construct is because they typically interact in a tightly coupled manner (Byrd et al, 2000). They are not easily differentiated in a clear and comprehensible way. Further, research has suggested that practitioners have acknowledged today's drive toward technology that enables faster development through employment of reusable software modules and object-oriented applications and data/databases (Byrd et al, 2000). Data flexibility has also been linked to data transparency. The importance of data transparency implies that organizations have found the value and importance of having access to information throughout the enterprise (Byrd et al, 2000). This capability is vital for sharing information to a broad range of users.

Modularity is a design method in which adhering to standards enables co-operative systems. The independence of modules allows replacement and sharing of modules with little interference with the rest of the system. Four characteristics of modularity follow:

1. Modules are co-operative subsystems that form a product, manufacturing system, business etc.
2. Modules have their main functional interactions within rather than between modules
3. Modules have one or more well defined functions that can be tested in isolation from the system.
4. Modules are independent and self contained and may be combined and configured with similar units to achieve a different overall outcome. (http://www.lboro.ac.uk)

Like integration, the modularity construct is also reliant on standardization. "The concept of modularity for applications has to do with isolating and standardizing as many business and systems processes as possible" (Duncan, 1995:48). A key characteristic of modularity is the ability of being replaced by another module without affecting any interacting components. This phenomenon results in system compatibility. The fundamental and enabling power behind modularity is interface and interaction standards (Miller et al, 1998). "The famous Lego blocks have a standardized interface - but no interaction. It is a very simple interface. Usually interfaces are more complex" (Miller et al, 1998:14).

Flexibility and In-flexibility

A study by Kayworth et al (2000) provides insight into the trade-offs associated with having an IT infrastructure that is too flexible or too standardized and rigid. The study pursues an optimal balance between localized exploitation of an IT infrastructure and enterprise-wide integration affecting IT infrastructure flexibility. The study is called "Facilitating Localized Exploitation and Enterprise-Wide Integration in the Use of IT Infrastructures: The Role of PC/LAN Infrastructure Standards," by Kayworth et al (2000). The study examines impacts that IT infrastructure standards have on the balance

between local office needs and the integration needs of the enterprise-wide organization. The constructs developed are specific attributes of standards that enable flexible infrastructures. The three attributes of standards are comprehensiveness, flexibility, and level of enforcement. The following paragraphs cover the three attributes developed by this study. The Air Force's IT infrastructure is guided and enabled by standards. Some of these standards can be seen in the Joint Technical Architecture (JTA) and the Air Force Joint Technical Architecture (AF-JTA).

The first attribute discussed by Kayworth et al (2000) is "level of enforcement." "Enforcement refers to actions taken by designers of formalized procedures to insure compliance" (Kayworth et al, 2000:57). It consists of three specific dimensions: education, monitoring, and sanctions. Education provides employees information on the procedures and standards. Monitoring is the process of collecting information on whether the standards are being complied with. Sanctions are actions taken toward correcting any problems encountered by people not following the standards. Education, monitoring, and sanctions provide the indicators for a high level of enforcement.

Comprehensiveness of standards is "the degree of formalization or the extent that written rules and procedures regarding … standards have been instituted within an organization" (Kayworth et al, 2000:58). A standard may exist for one aspect of the data stored in a database such as the field length. A standard might also entail a more comprehensive guide by standardizing the field length, naming convention, and its primary key. An enabling view of comprehensive standards is that it provides guidance or detailed templates. This allows management of complex enterprise-wide infrastructures that would otherwise have little direction (Kayworth et al, 2000).

Kayworth et al explains that comprehensive PC/LAN standards detail a varied spectrum of issues that includes purchasing, security, maintenance policies, LAN protocols, operating systems, networking software, email systems, memory requirements, processor requirements etc.

Kayworth et al's research finds that comprehensiveness of standards is not the all-inclusive factor for high responsiveness to localized exploitation. Comprehensive standards can be overly complex. Their results suggest moderate comprehensiveness or some situational balance. Finding a balance unique to each IT infrastructure may be necessary if standards are to be used as enabling mechanisms.

They also hold that the ability to react to unique non-routine opportunities is critical to maintaining a competitive edge. However, an aspect of comprehensiveness is that standards can become too restrictive and limit the ability to quickly respond to mission or market conditions. They result in overly comprehensive standards that hamper flexibility. Still, standards enable modularity and integration resulting in infrastructure flexibility. Thus, standards may cut both ways. Standards that are low in comprehensiveness fail to meet the company wide need to facilitate economies of scale and enterprise-wide integration. At the same time, excessive standards may limit the local managers ability to provide new or improved capabilities as they become available. Standards that are well balanced may provide the needed enterprise-wide standards and enable managers the flexibility to seize opportunities as they emerge (Kayworth et al, 2000). Understanding the concept that different levels of comprehensiveness promote different results in different areas of the infrastructure may be a vital finding. It provides knowledge on how standardization affects infrastructure flexibility. In the absence of

such knowledge, struggles between the desire for enterprise-wide integration and the autonomous actions of local parts of the organization emerge. This imbalance leads either inflexible infrastructures or overly flexible infrastructures.

The third attribute identified by Kayworth et al is flexible standards. The definition of flexible standards is “the latitude in deviating from the prescriptions of action described in…standards” (Kayworth et al, 2000:59). Kayworth et al states that the flexibility or restrictiveness of a standard relates to the working or functioning of the standard itself. Standards that have greater flexibility enable more varied options, whereas standards that are restrictive limit options. An organization may choose to allow a limited choice among standards allowing flexibility. An organization may also limit the choice to one standard. “For example, flexible standards might allow the choice of any operating system platform (Unix, NT, or Novell), whereas restrictive standards would recommend a specific operating system” (Kayworth et al, 2000:59).

Kayworth et al’s states that flexibility of standards is important and that organizations need to consider flexibility of standards when designing infrastructures. As stated previously restrictive standards can create a highly controlled enterprise-wide infrastructure. However, these benefits may be offset by the limitation on flexibility and entrepreneurship. Contrary to rigid standards, flexible standards enable a high degree of flexibility at local levels, but the high degree of flexibility may be at the loss of the enterprise-wide infrastructure. Other research has suggested the implementation and design of standards should have a balance between restrictiveness and control (Kayworth et al, 2000).

Kayworth et al (2000:59) states “flexible standards are less coercive and facilitate an organic decision-making environment; managers could adapt the PC/LAN infrastructure to novel or unanticipated IT demands placed upon their business units.” Flexible infrastructures are more than good for reacting to unplanned requirements; they also raise perceptions about the infrastructure as being responsive to localized exploitation. Lack of flexibility may constrain the options of business managers (Kayworth et al, 2000). They may also be seen as bad business when unanticipated modifications are required for IT infrastructures. Even though a specific level of flexibility was previously acceptable, new circumstances may result in a need to adjust the level of flexibility. Otherwise, organizational units are likely to consider IT standards, as not being responsive to their localized mission or business needs. Such situations may lead local units to make autonomous decisions and implement their own standards. This may adversely affect enterprise-wide integration. It is also likely to reduce the compatibility and overall effectiveness of the IT infrastructure (Kayworth et al, 2000).

Research accomplished prior to Kayworth et al’s research has suggested that a higher level of flexibility is required to leverage local IT responsiveness (Ives et al, 1991; Hanseth et al, 1996; Duncan, 1995; Allen et al, 1991; Boynton & Zmud, 1987). However, in Kayworth et al’s research, the results showed that higher flexibility of standards resulted in lower localized exploitation. Kayworth et al (2000:71) specifically stated, “High responsiveness to localized exploitation was observed…in spite of very low level of flexibility accompanied by moderate-high levels of enforcement.” This opposing discovery suggests that flexibility, levels of enforcement, and comprehensiveness are not

adequate enough to predict responsiveness of infrastructure standards to localized exploitation. The conclusion is that other constructs may play a role in these relationships. Nonetheless, this study provides background in the issues of flexibility and inflexibility at the enterprise and local levels.

Flexible IT Component Designs

To gain a better understanding of design issues that may affect IT infrastructure flexibility this study has pursued research contributing to flexible designs. The knowledge gained from researching the designs for flexible IT infrastructures may help in the analysis of the Air Force's IT infrastructure. Establishing a flexible IT infrastructure design that addresses the following four flexibility qualities previously discussed in this chapter is presented. The flexibility qualities are:

1. Compatibility of the platform
2. Connectivity of the network
3. Modularity of the data
4. Modularity of the applications
   (Duncan et al, 1995)

Since these flexibility qualities measure IT infrastructure flexibility, they offer constructs on which a design of an IT infrastructure can focus. The design must ensure the 1) compatibility of the platform, 2) the connectivity of the network, etc.

Mindful of the infrastructure components (platform, network/telecom, data, applications) that make up the infrastructure, each of the components will be separately explored for its contribution to flexible infrastructures. Guidance set by Earl (1989:95) stated, "This concept of architecture implies…that although each element can be, and has to be, tackled separately, they are interdependent. Not only is architecture seeking to achieve an infrastructure that is greater than the sum of the parts, but each element influences the other." All of the components are separate in their function, but interact

and share with one another to form the infrastructure. Therein also lies part of the definition of an infrastructure, which is sharing. An IT infrastructure is the "set of shared, tangible, IT resources that provide a foundation to enable present and future business applications" (Duncan, 1995:39). The point being made is that although the components are separate they also work together. Sharing and working together requires interfaces, and each of these components has interfaces that are at the very crux of sharing. Blackenfelt et al (1989:1) states, "the interfaces must be standardized in each of the domains to allow the ability of full exchange of components." Focusing on the interface helps identify interface standards, which enable interaction required to construct an infrastructure. Sharing and reuse are at the very center of IT infrastructure flexibility (Duncan, 1995). Identifying these interfaces within each of the infrastructure components will be a guiding method to design a flexible infrastructure.

A quick example of the interactions can be seen when one platform requires communication with another. Platform A has sales data that platform B needs for computing weekly revenue. Platform B makes a request through the network to Platform A requesting the sales data. Platform A receives the request and sends the data to Platform B, where platform B uses an applications to total the revenue gathered throughout the week for a weekly total. With even one component missing the business goal of totaling weekly revenue cannot be accomplished. In this case, the infrastructure does not support the business needs. A further view into the IT infrastructure shows the platforms interacting with applications need operating system calls to control the applications environment. The platform performs operations on the storage and receiving of data and must interface with networks to receive data and identify what data format is

being sent. Applications require interaction with the network to enable applications access to data stores across the network. Applications also require the identification and manipulation of data for processing and are stored on the platform. The network is the road that connects all the data and applications components from one platform to another.

Flexible Platform Designs

The platform's flexibility quality is compatibility, which is the "ability to share any type of information across any technology component" (Byrd et al, 2000:171). Yacoub et al (2000:2) states "interfaces define the component interaction with the platform." Yacoub et al also states that the platform interfaces consists of the hardware, operating system, compilers, and communication channels (protocol stacks). As discussed earlier the interface is the source of sharing and reuse and an essential aspect to standardize. Thus, areas requiring standardization for compatible platforms and flexible infrastructures are:

1. Operating System
2. Hardware Platform
3. Communication channels (and protocol stacks)
4. Compilers (if required to compile the component)
   (Yacoub et al, 1999:3)

These standards may suggest that compatibility only exists among a single manufacturer's corresponding products (Succi et al, 2000). Thus, someone may hold the view that an organization requires the same operating system on every workstation to achieve compatibility. As convenient as this may seem, relying on one product base may not always be in the best interest of an organization, and a mixture of different platforms may be required. For that reason, when standardizing on an operating system, hardware platform, etc., the ability to share and recognize each other's data and communication

protocols is very important in selecting more than one standard. As other infrastructure standards are created, the platform must be updated to represent those standards. If a data standard is created for an organization, then the platform must be able to identify, store, and manipulate the data to enable sharing and reuse. Thus, compatibility is to some degree reliant on the other standards in the infrastructure. This element of relying on other infrastructure components leads back to a discussion of interfaces. Once the platform interfaces are standardized, the platform can become compatible with other components. One example is a platform's need for a compatible interface with the network to enable connection to other computers.

Data Flexibility Designs

Another component that shares in the infrastructure is the data component. Data's quality for enabling flexible infrastructures is modularity (Duncan, 1995; Byrd et al, 2000). Data is considered modular when able to "add, modify, and remove any…data components of the infrastructure with ease and with no major overall effect" (Byrd et al, 2000:171). To enable this modular environment all the characteristics of the data must be contained within the data module itself, without external dependency (Gershenson et al, 1999). Within the modular structure the modularity principle of hierarchy (Gershenson et al, 1999) enables representation of different levels of detail and subassemblies of the data (Gershenson et al, 1999). A sort of taxonomy and uniformity within the module are a result.

Duncan's research noted, "as data…components become independent and reusable, they become part of infrastructure" (Duncan et al, 1995:43). As discussed, reusability requires a standard interface, and in order for data to truly be modular, a

standard interface must be identified. One example of a standardized interface could be a tag or descriptor of the types of data being represented in the data format. In a Microsoft Word data file, the file has a descriptor inside the file that says it is a word document. Once an application reads this descriptor the application knows what the document is for and that the contents contain MS Word data. But, if we consider data to be truly modular, all the data must look the same from the outside (Gershenson et al, 1999), i.e. replaceable by other data. MS Word data looks different from jpeg files, and jpeg files look different from text files. Therefore, a design must be pursued that has a similar structure for every kind of data whether it is voice, text, video, graphics, etc. Accomplishing this requires all data types to have enough format standardization so that applications can identify what type of data is contained and the general topics or tags (in XML) the data file contains. The data file may contain voice, video or text, but with data type descriptors standardized within the data file it is therefore recognizable to applications and platforms. This is an example of data encapsulation with a standardized tag structure enabling data to become modular and flexible enough to handle any data type so required by users. Striving toward standardizing on a modular data format and a standard interface represents that structure. Once, these standards are in place, the tags can identify all the necessary information inside the data. Data design issues that are needed toward this end follow:

Modular Data Designs:

1. <u>Data encapsulation</u>: Self-contained, high cohesion and low coupling (Gershenson et al, 1999).
2. <u>Standardized tag structure</u>: Universally identifies the data type and use.

3. Separation of content and structure within module: Also called optional structure definition, similar to document type definition (DTD). Allows the content and structure to be separated (Deadman, 1999).
4. Standard hierarchical attribute structure within module: Helpful in discerning levels of detail and showing subassembly interactions (Gershenson et al, 1999).

Application Flexibility Designs

The applications component of the infrastructure shares flexibility qualities with data because the applications component is also measured by modularity. Byrd et al (2000:194) states "modularity is the ability to add, modify, and remove any software, hardware, or data components of the infrastructure with ease and with no major overall effect." Byrd et al (2000:194) also stated "items of the modularity factor suggest that the survey respondents acknowledged the trend toward faster applications development (e.g., reusable software modules, object-oriented technologies."

The concept of modularity for applications has to do with isolating and standardizing as many business and systems processes as possible. At the most elementary level, IS organizations can modularize routine system processes such as data calls. At a higher level, an IS organization may routinely store as many rules and functions as possible separately from the main application. Encapsulated in separate modules, business rules, implementation code, and individual processes may become far more accessible (Duncan, 1995).

Therefore, as long as the principles of modularity are followed implementations of those principles should become flexible. The primary concept in modular applications is the component's interface (Dennis, 1997). This affects the manner in which the

components interact. The procedure call is the most common type of interface in application development. When the procedure call is initiated a module carrying input values is supplied to the application for constructing output values available to the person or computer making the request (Dennis, 1997). An outsider's view of the applications sees the data being input into the application and an output received with no visible interaction within the application. This is an example of one of the modularity principles of "information hiding."

The following design attributes follow the modular principles and provide the flexibility this research pursues. "To attain the full benefits of modular programming the support provided by the computer system support of the component interfaces should meet the following requirements:" (Dennis, 1997:2).

1. Information hiding: The user of a module must not need to know anything about the internal mechanisms of the module to make effective use of it.
2. Invariant behavior principle: The functional behavior of a module must be independent of the site or context from which it is invoked.
3. Data generality principle: The interface to a module must be capable of passing any data object an application may require.
4. Secure arguments principle: The interface to a module must not allow side-effects on arguments supplied to the interface.
5. Recursive resource management principle: Storage management for data objects must be performed by the computer system and not by individual program modules.
(Dennis, 1997)

Network Flexibility Designs

The fourth infrastructure component is network/telecommunications. Networks/telecommunications enable flexible infrastructure connectivity. Connectivity has been described as the "ability of any technology component to attach to any of the other components inside and outside the organizational environment" (Byrd et al,

2000:171). Once again, the interface is an important aspect of an infrastructure component's connectivity. The primary reason for the importance of the network component is the large variety of connecting locations. Examples are desktop computers, to PDA's, to cell phones, etc. In addition, the network itself has several standards such as Ethernet, token ring, FDDI, etc. So the question is what level of detail is needed for standards that enable connectivity leading to infrastructure flexibility? An initial answer is to start at the interface. As long as interfaces can connect to one another and transfer data, and the destination receives the data in the same format it was sent, connectivity is achieved. This is similar to a black box where you input data into the box and do not necessarily care how the data is processed as long as the output is as expected. The data may travel from a token ring network to a fiber backbone out to a satellite connection that eventually sends the data back down to earth half a planet away to a satellite receiver, fiber backbone, and token ring network again until is finally gets to its destination at a workstation.

> Consider the everyday example of the telephone system. When you dial a number, electrical signals are sent to the telephone exchange to establish a connection. The receiving device recognizes and interprets the signals and responds. The sending and receiving system can communicate because they share the same standards, even though they use entirely different voltages, signaling equipment, and so forth. An even more mundane example of a standard interfaces is the two/three-pin plug we take for granted when we plug an electrical appliance into the wall. If only the computer and telecommunications field had evolved along the same path as telephones and appliances! (Keen, 1991:199)

Another view of network flexibility shows there may be some additional characteristics to networks that enable connectivity and flexibility. Feitelson et al (2000) describes three factors that compose network flexibility. The factors are node flexibility,

link flexibility, and temporal flexibility. Node flexibility is the ease of adding network nodes (point of access). Without having the ability to add nodes as required, flexibility is clearly limited. An organization may require additional nodes for a new department. These nodes must be created and working before a competitor can set up their new department and take advantage of the new functionality both organizations are striving toward. Link flexibility is the ease of adding additional links between network nodes. This factor enables increased network connectivity and alternative route options within the network. Temporal flexibility is the extent to which infrastructure use requires coordination so that one user cannot prevent others from using the network. One example of this factor is the use of satellite transmission. If one user has limited the transmission abilities of others needing to use the transmission, then the coordinating need between the two parties would seemingly restrict the flexibility of using the transmission as needed. In some shape or form all of these factors affect network connectivity. Without the ability to add new nodes, whether a telephone node, fiber node or wireless PDA node, connectivity is affected if the nodes cannot be reached. Without redundant links within the network, any failure can terminate connectivity. In addition, without freedom to use the network without coordination, users may be limited by short notice needs as well as long-term scheduling conflicts.

Considering this discussion, the following design issues are presented enabling network connectivity and ultimately infrastructure flexibility:

1. Dynamic node addition/elimination (Feitelson et al, 2000).
2. Redundant links (Feitelson et al, 2000).
3. User access independence (Feitelson et al, 2000).

4. One network, all data (i.e. similar concept to ISDN, standardize all the data connections into one network (voice, text, fax, video, etc.) This enables cross-organizational information flows (Keen, 1991).
5. Standard physical input/output interfaces (e.g. two/three-pin plug).

Academic Review Summary

All the research on IT infrastructure flexibility up to this point has focused on IT infrastructure flexibility. Duncan's research produced the constructs of platform compatibility, data modularity, application modularity, and network connectivity as the measuring tools for infrastructure flexibility (Duncan, 1995). Byrd et al (2000) reinforced Duncan's research by producing similar results in measuring infrastructure flexibility. The combination of these two research products has formed a foundation for infrastructure flexibility constructs and provided instruments for evaluating IT infrastructure flexibility. However, the Air Force is not known to have taken advantage of this research to further understand and improve the Air Force's IT infrastructure. The goal of this research is to utilize Byrd et al's (2000) "Complete Questionnaire for the Information Technology Flexibility Survey," to establish the level of flexibility within the Air Force's IT infrastructure. In doing so the modularity of data and applications will be analyzed as well as the integration of computer platforms and networks/telecommunications. Data generated from the survey can be analyzed to provide evidence of where the Air Force's IT infrastructure is situated.

Summary

The Air Force is guided by the direction of Joint Vision 2020. Joint Vision 2020 enables preparation for future defense of the United States. Within this direction, the Air Force's IT infrastructure is guided to address current and future threats. This direction

has molded the Air Force's IT infrastructure and continues to lead it in the future. However the Air Force has identified many problems with the current IT infrastructure in supporting this future. Some examples are:

1. Inability to globally share resources
2. IT acquisition process is unable to keep pace with rapidly changing technology
3. Funding of stovepipe programs
4. Multiple transmission systems and architectures managed by different entities
5. Inadequate application and enforcement of standards
6. Too many standards
   (CONOPS for Air Force Information Enterprise)

One solution is to provide a flexible IT infrastructure (CONOPS for Air Force Information Enterprise). The Air Force has currently identified this as a means to the future. However, to provide a flexible infrastructure the current state of flexibility must be known. This study will assess the current state of the Air Force's IT infrastructure flexibility.

The instrument used for measuring flexibility utilizes two indicators. The indicators are modularity and integration. Modularity measures the flexibility of data and applications. Integration measures the flexibility of computer platforms and networks/telecommunications. A breakdown of these constructs can be seen in Figure 2.

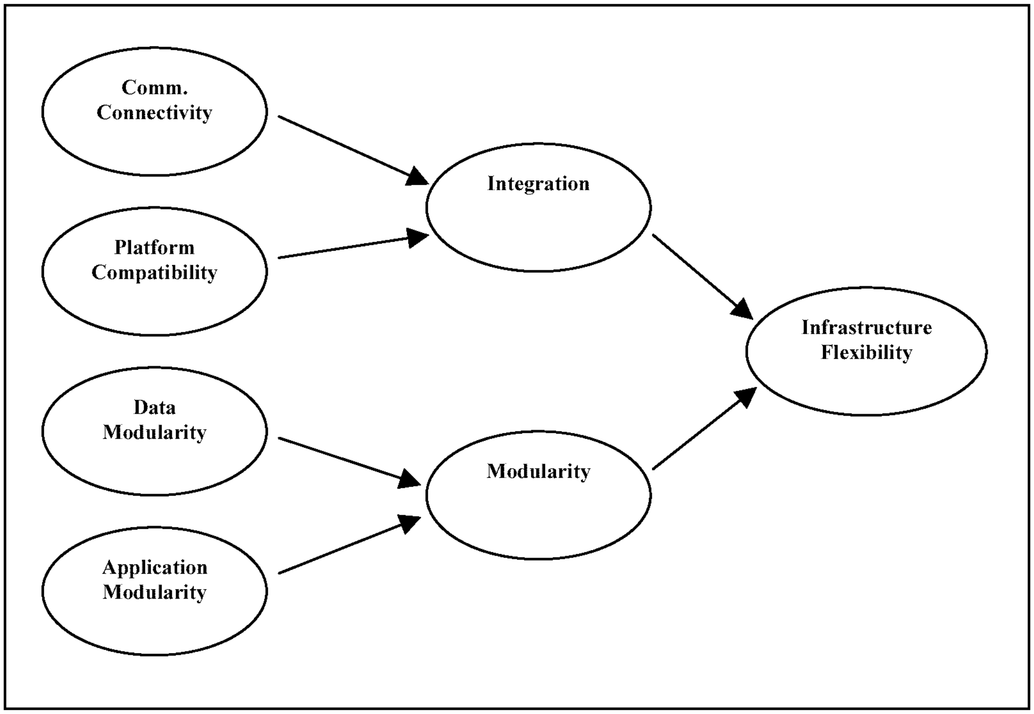


Figure 2: Flexibility Construct Diagram (Byrd et al, 2000)

Definitions of the constructs measuring IT infrastructure flexibility are:

1. Integration: Consists of integration between IT connectivity and IT compatibility.

    a. IT Connectivity: The ability of any technology component to attach to any of the other components inside or outside the organization. (Byrd et al, 2000)
    b. IT Compatibility: The ability to share any type of information across any technology component. (Byrd et al, 2000)

2. Modularity: The ability to add, modify, and remove any software or data components of the infrastructure with ease and with no major overall effect. Modularity also relates to the degree to which IT software and data can be either seamlessly or effortlessly diffused into the infrastructure or easily supported by the infrastructure (Duncan, 1995). Modularity consists of the application functionality and data transparency sections in the survey.

III. Methodology

Overview

This chapter outlines the methodology to be used in researching questions on the flexibility of the Air Force's IT infrastructure. Steps for presenting the research methodology are:

1. Review the indicators of IT infrastructure flexibility
2. Explain how to use these indicators in finding the Air Force's level of flexibility
3. Describe the population to be researched
4. Explain the research design
5. Present the research survey instrument
6. Cover the process for implementing the research
7. Detail the methods of analysis

The Air Force uses a number of separate IT infrastructures. These are the unclassified, secret, and top-secret infrastructures. This study assesses the unclassified IT infrastructure.

Flexibility Indicators

Based on the model presented in Chapter 2, the indicators that will be used for measuring IT infrastructure flexibility are modularity and integration. Modularity measures the flexibility of data and applications, and integration measures the flexibility of computer platforms and networks/telecommunications (Byrd et al, 2000). A survey developed by Byrd et al has operationalized these constructs. The methodology behind

implementing this survey is detailed in the remainder of this chapter. Twenty exploratory questions based on a five-point likert scale is the method for assessing the Air Force's IT infrastructure flexibility. The questions are:

A. Integration survey questions with respect to communication connectivity:

1. Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI).
2. There are very few identifiable communications bottlenecks within our organization.
3. Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).
4. Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).
5. All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing data and processing).
6. Our organization utilizes a virtual network or VLAN to connect to end users.

B. Integration survey questions with respect to platform compatibility:

7. Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office.
8. End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).
9. Software applications can be easily transported and used across multiple platforms.
10. Our organization offers a wide variety of types of information to end users (e.g., multimedia).
11. Our user interfaces provide transparent access to all platforms and applications.
12. Our organization provides multiple interfaces or entry points (e.g., Web access for external end users).

C. Modularity survey questions with respect to applications

13. Reusable software modules are widely used in new systems development.
14. End users utilize object-oriented tools to create their own applications.

15. IT personnel utilize object-oriented technologies to minimize the development time for new applications.
16. Legacy systems within our organization restrict the development of new applications.

D. Modularity survey questions with respect to data

17. Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).
18. Mobile users have ready access to the same data used at desktops.
19. Our organization easily adapts to various vendors' database management systems protocols and standards.
20. Data captured in one part of our organization are immediately available to everyone in the organization.

An additional question was included for explore differences in views between junior Air Force IT leaders and senior Air Force IT leaders.

1. Do senior IT leaders have a different view than junior IT leaders on IT infrastructure flexibility?

Population

This study's population of interest is Air Force IT support personnel. Air Force IT support personnel include military, government service, and contractors. The developer of the instrument (Byrd et al, 2000) surveyed Chief Information Officers, Vice Presidents of Information Services, Directors of Management Information Systems (MIS), and Database Administration Directors in civilian organizations. The primary reason these people were targeted is their knowledge and corporate IT experience (Byrd et al, 2000). This study takes a similar approach and directs this study toward knowledgeable and experienced Air Force IT professionals. However, government service and contractors were not included in this study for legal and procedural reasons.

The people selected were military personnel in communications and computer career fields. An additional criterion is that they were at least the rank of Captain for officer, and a minimum of Master Sergeant (MSGT) for enlisted. Those below these ranks were excluded due to their inexperience suggested by their time-in-service. Government service employees were omitted because of the complexity of dealing with unions across the Air Force as well as the amount of time required to acquire permission. Contractors were omitted because of the complexity of dealing with contracts, and with difficulties identifying a pool of contractors experienced enough with the Air Force and its representative organizations. The groups that have been selected are Air Force Captains through Colonel in the 33S career fields (2,821 total), and Master Sergeant (MSGT) to Chief Master Sergeant (CMSGT) in the 3COX2 career field (270 total). Additionally, 11 Generals in the 33S career field have also been selected. The sample population for this study is 3,102.

Research Design

The design of this study is a cross-sectional, five-point likert scale survey with a stratified random sample. It was administered via the Internet. The study is cross-sectional, or collecting data at one time point (Dooley, 2001). This is because the goal is finding the current level of IT infrastructure flexibility. A web-based survey was selected to provide a convenient and fast means of gathering data. The web-based survey enables research subjects to receive notification and directions via e-mail providing an economic and speedy dissemination (Dooley, 2001). Additionally, completing the survey on-line allows an instant view of responses. The survey was developed by Byrd et al (2000) and

was validated through statistical processes of confirmatory factor analysis and t-tests (Byrd et al, 2000, 195).

The population in this study is stratified between junior Air Force IT leaders and senior IT leaders. The stratification provides a means for comparison between junior IT leaders and senior IT leaders. Senior Air Force IT leaders have been identified as Colonels and Generals. Junior Air Force IT leaders are Captain through Lieutenant Colonel in the officer ranks and MSgt through CMSgt in the enlisted ranks. Within the junior IT leaders group, research subjects were randomly selected. "Random sampling provides the best way of achieving equal-probability sampling" (Dooley, 2001). The entire population of senior IT leaders was selected, this was due to the low population size.

The intent of this survey is to measure the technical IT infrastructure flexibility. The survey by Byrd et al (2000) was designed to measure this construct. The survey was "validated and deemed reliable through fairly rigorous statistical processes of confirmatory factor analysis and t-tests" (Byrd et al, 2000). The areas of inquiry for measuring IT infrastructure flexibility are integration and modularity. Questions in the survey operationalized both the modularity and integration constructs. Seventeen questions address integration and sixteen questions address modularity. Each question is ranked on a five-point likert scale with one being "Strongly Disagree" up to five representing "Strongly Agree." Additionally a "N/A" field was included to provide a complete covering of possible answers as recommended by AFI 36-2601 (Section A10.1.2.). The demographic questions on the survey capture job titles, job type, organizational level, rank, major command (MAJCOM), Air Force Specialty Code

(AFSC), gender, years experience in IT, number of people supported, and highest level of education. This was the only part of the survey modified from its original form. The questions were modified to support military specific demographics such as rank, MACJOM, and AFSC. The survey number issued by the Air Force Personnel Systems (AFPC) Air Force Survey Branch to conduct this study was USAF SCN 01-114.

Implementation Process

The implementation process consisted of developing the web survey, selecting the sample group, sending e-mails to selected research subjects, and analyzing the data. The first step of building the web survey was creating a web page in Microsoft FrontPage. Once the web page was developed a Microsoft Access Database was created to store the submitted surveys. The second step was to randomly select research subjects. A list of Air Force IT support personnel was attained from AFIT's Registrars office. The selection of subjects was then accomplished by using a random number generator to select 912 junior Air Force IT leaders. The number of senior IT leaders selected was 88, which is the entire population. A total of 1,000 people were selected to perform the study. This is inline with Byrd et al's (2000) study that sent 1,000 surveys. Additionally, the recommended sample size using a power formula (AR-600-46, 1974) was determined to be 248. Thus a 24% or better response would provide the recommended or better sample response size. The third step was to send research subjects their e-mail notifications. The e-mails contained information regarding the study's purpose, the AFPC control number, and directions for accessing the survey via hyperlink.

Analyzing the Data

Once the surveys were completed, and the data collected, analysis of the data was performed. The mean, standard deviation, and variance were computed for each question. Then a mean of means was computed for an overall level of IT infrastructure flexibility. The data was then copied to a statistical tool called Jump. Jump computed the mean, standard deviation, lower confidence level, and upper confidence level. A confidence level of 95% was computed for the upper and lower levels. Computing these statistics provided the foundation for testing the level of IT infrastructure flexibility.

Summary

This chapter provided the methodology used to gather information on the level of IT infrastructure flexibility in the Air Force. A web-based survey was used to gather the research data. The subjects for this study were stratified into junior Air Force IT leaders and senior Air Force IT leaders. Within the junior IT leaders group the research subjects were randomly selected. Within the senior group the entire population was selected. Once these groups were identified e-mails were sent informing the research subjects of the study and the web location for its access. After the subjects completed the survey, results were computed to provide a means of analysis. The next chapter provides an analysis of the survey responses.

IV. Analysis

Introduction

This chapter analyzes data obtained from implementing the research methodology from Chapter Three. Forty percent of the e-mails inviting participation in the survey were immediately rejected, due to inaccurate e-mail addresses. The response rate was adjusted to eliminate the forty percent that never reached their destination. The resulting response rate for junior IT leaders was 37 percent and 22 percent for senior IT leaders. An overall response rate for the study was 36 percent. In total 216 surveys were completed. Factor analysis completed on the twenty questions resulted in four constructs. This is similar to Byrd et al's findings from first order factor analysis. Additionally, Cronbach's alpha was computed to have a value of .864. This suggests a strong relationship between constructs.

Analysis Overview

The first part of this chapter displays the results of the demographic questions. The second part focuses to the Air Force's IT infrastructure flexibility. This is accomplished by:

1. Analyzing the twenty likert-type questions
2. Computing the level of modularity and integration

Demographics

Male	Female
189 (87%)	27 (13%)

MSgt	SMSgt	CMSgt	Captain	Major	Lt Colonel	Colonel	General
13 (6%)	1 (0%)	0 (0%)	188 (54%)	51 (24%)	21 (10%)	12 (6%)	0 (0%)

33SX	3COX2	Other
192 (89%)	8 (4%)	14 (7%)

High School	Associate's	Bachelor's	Master's	PhD
3 (1%)	4 (2%)	25 (12%)	140 (80%)	4 (2%)

Year Experience in IT

0	1-4	5-9	10-19	20-30
4 (2%)	24 (10%)	60 (25%)	91 (37%)	64 (26%)

Professional	Middle Mgt	Executive
38 (18%)	126 (58%)	52 (24%)

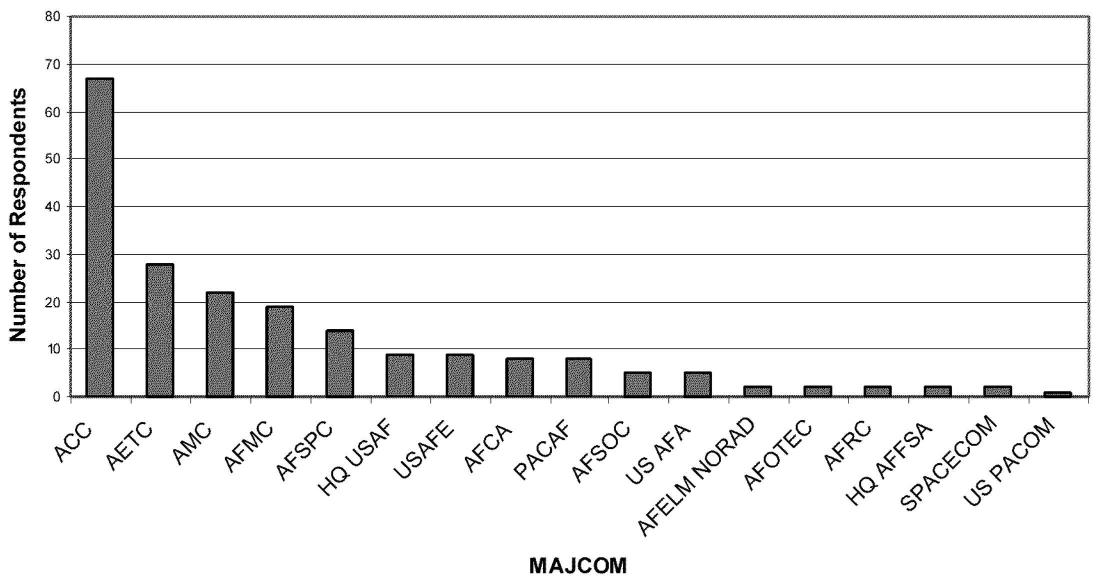
Base	MAJCOM HQ	Center	FOA/DRU	Air Staff	Detachment	Numbered AF	Other
59 (28%)	59 (27%)	18 (8%)	22 (10%)	11 (5%)	4 (2%)	8 (4%)	35 (16%)

Number of People Supported

0	22 (10%)
1-10	2 (1%)
11-50	8 (4%)
51-100	12 (6%)
101-1000	52 (24%)
1001-10000	76 (35%)
10001-20000	12 (6%)
20001-60000	8 (4%)
60001-2000000	21 (10%)

Table 3: Respondent Demographic

Figure 3: Major Command (MAJCOM) of Research Respondents



Demographic Findings

Several of this study's demographic questions closely characterized the true populations of the Air Force IT support personnel. This is indicated by proportion of males to females, Air Force Specialty Code (AFSC), and respondents from different MAJCOM's. Results from computing the gender statistics concluded that 87 percent of the respondents were males and 13 percent were females. This is close to the 85 percent males and 15 percent female population proportion in the combined 33S and 3COX2 career fields according to the Air Force Personnel Center (AFPC) demographic data. The Air Force Specialty Code (AFSC) also provides a reasonable representation of the population. This study shows that 89 percent of the respondents had an AFSC of 33S (Officers in Communications/Computers). The true value of the population is 91 percent.

Major Command (MAJCOM) demographics are another area that provides support for equivalent representation. All nine Air Force MAJCOM's and a couple of DoD MAJCOM's were represented. The DoD MAJCOM's represented in this study were United States Pacific Command (US PACOM), North American Defense (NORAD), and the United States Space Command (US SPACECOM). Respondents from these organizations provide valuable information by representing different links between the Air Force and external branches of the DoD. Links to other countries is also represented by North American Defense's (NORAD) relationship with Canada.

Overview of Flexibility Questions

The following section displays the statistics and levels of agreement on each of the survey questions. The following areas were addressed to measure the Air Force's IT infrastructure flexibility.

1. Integration: Network/Telecom Connectivity
2. Integration: Platform Compatibility
3. Application Modularity
4. Data Modularity

A not applicable "N/A" option was provided for each survey question. The resulting score of a N/A selection is zero. The N/A scores have been removed in computing the averages and percents. This provided a focus on the varying degrees of flexibility values (1=STRONGLY DISAGREE through 5=STRONGLY AGREE).

The following figures categorize the number of respondents that "Agree" with the questions, "Disagree," or have a "Neutral" view. Agree consists of respondents that selected either a 4 (Agree) or 5 (Strongly Agree) on the survey. Disagree consists of

respondents that selected either 1 (Strongly Disagree) or 2 (Disagree). Neutral consists of the respondents that selected 3 (Neutral). The total number of selections made on each category is followed by the percentage of people selecting that question. Each category is ordered from the largest percent of agreement.

Table 4: Communication Connectivity Statistics

INTEGRATION: COMMUNICATION CONNECTIVITY	Mean	Std Dev	N	Disagree	Neutral	Agree
All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing and processing data).	3.814	1.123	194	26 (14%)	38 (20%)	130 (66%)
Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI).	3.772	1.090	189	24 (13%)	45 (24%)	120 (63%)
Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).	3.651	1.090	195	27 (14%)	50 (26%)	118 (60%)
Our organization utilizes a virtual network or VLAN to connect to end-users.	2.960	1.379	176	76 (44%)	29 (16%)	71 (40%)
Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).	2.887	.997	204	77 (37%)	68 (34%)	59 (29%)
There are very few identifiable communications bottlenecks within our organization.	2.673	1.096	205	100 (49%)	55 (27%)	50 (24%)

Ex: Total Selected (% of N) = 50 (40%)

Neutral = Total 3's (Neutral)
Agree = Total 4's (Agree) + 5's (Strongly Agree)
Disagree = Total 1's (Disagree) + 2's (Strongly Disagree)

Table 5: Platform Compatibility Statistics

QUESTIONS MEASURING INTEGRATION: COMPATIBILITY	Mean	Std Dev	N	Disagree	Neutral	Agree
End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).	3.917	1.151	206	31 (15%)	22 (11%)	153 (74%)
Our organization offers a wide variety of types of information to end users (e.g., multimedia).	3.802	1.008	202	25 (12%)	36 (18%)	141 (70%)
Our organization provides multiple interfaces or entry points (e.g., Web access for external end users).	3.545	1.124	198	40 (20%)	34 (17%)	114 (63%)
Software applications can be easily transported and used across multiple platforms.	3.245	1.149	188	50 (27%)	50 (27%)	88 (46%)
Our user interfaces provide transparent access to all platforms and applications.	3.100	1.134	190	58 (31%)	53 (28%)	79 (41%)
Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office.	2.782	1.215	188	84 (45%)	47 (25%)	57 (30%)

Ex: Total Selected (% of N) = 50 (40%)

Neutral = Total 3's (Neutral)
Agree = Total 4's (Agree) + 5's (Strongly Agree)
Disagree = Total 1's (Disagree) + 2's (Strongly Disagree)

Table 6: Application Modularity Statistics

APPLICATION MODULARITY	Mean	Std Dev	N	Disagree	Neutral	Agree
Legacy systems within our organization restrict the development of new applications.	3.559	1.134	161	33 (21%)	37 (23%)	91 (55%)
IT personnel utilize object-oriented technologies to minimize the development time for new applications.	3.023	1.131	133	45 (33%)	39 (29%)	49 (37%)
Reusable software modules are widely used in new systems development.	2.838	1.117	136	51 (38%)	45 (32%)	40 (30%)
End users utilize object-oriented tools to create their own applications.	2.195	1.050	128	85 (65%)	25 (20%)	18 (15%)

Ex: Total Selected (% of N) = 50 (40%)

Neutral = Total 3's (Neutral)
Agree = Total 4's (Agree) + 5's (Strongly Agree)
Disagree = Total 1's (Disagree) + 2's (Strongly Disagree)

Table 7: Data Modularity Statistics

DATA MODULARITY	Mean	Std Dev	N	Disagree	Neutral	Agree
Mobile users have ready access to the same data used at desktops.	2.851	1.197	188	77 (41%)	51 (27%)	60 (32%)
Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).	2.883	1.146	145	52 (36%)	50 (35%)	43 (29%)
Data captured in one part of our organization are immediately available to everyone in the organization.	2.432	1.085	190	107 (56%)	44 (23%)	39 (21%)
Our organization easily adapts to various vendors' database management systems protocols and standards.	2.539	.968	167	83 (50%)	54 (32%)	30 (18%)

Ex: Total Selected (% of N) = 50 (40%)

Neutral = Total 3's (Neutral)
Agree = Total 4's (Agree) + 5's (Strongly Agree)
Disagree = Total 1's (Disagree) + 2's (Strongly Disagree)

Junior and Senior IT Leaders

The final exploratory question of the study asks whether senior Air Force IT leaders have a different view than junior Air Force IT leaders on the Air Force's IT infrastructure flexibility. The mean survey score for junior IT leaders is 3.06. The rating for senior IT leaders is 3.11. To compute a mean score, the legacy systems question was modified to represent the majority of questions where 1 indicated inflexibility and 5 indicated flexibility. One question within the survey has a significant difference between the two groups. The question is whether external end users have multiple interfaces or entry points (e.g., Web access) for access. Junior IT leaders have a mean score of 3.50. Senior IT leaders have a mean score of 4.27 (See Figures 4). The P-value is .027 with an F ratio of 4.97 (See Table 8 for list of all questions).

Junior Leaders Statistics		**Senior Leaders Statistics**	
Mean	3.064	Mean	3.111
Std Dev	0.514	Std Dev	0.710
N	20	N	20

Figure 4: Junior and Senior Leader Respondent Statistics

Table 8: Differences Between Junior and Senior IT Leaders on Flexibility

Differences on Integration (Compatibility)	F Ratio	Prob > F
End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).	0.596	0.441
Our organization offers a wide variety of types of information to end users (e.g., multimedia).	0.995	0.320
Our organization provides multiple interfaces or entry points (e.g., Web access for external end users).	4.970	0.027
Software applications can be easily transported and used across multiple platforms.	1.115	0.292
Our user interfaces provide transparent access to all platforms and applications.	1.809	0.180
Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office.	0.023	0.880

Differences on Integration (Connectivity)	F Ratio	Prob > F
All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing and processing data).	0.220	0.639
Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI).	0.039	0.842
Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).	0.049	0.824
Our organization utilizes a virtual network or VLAN to connect to end-users.	0.287	0.592
Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).	0.024	0.875
There are very few identifiable communications bottlenecks within our organization.	0.062	0.803

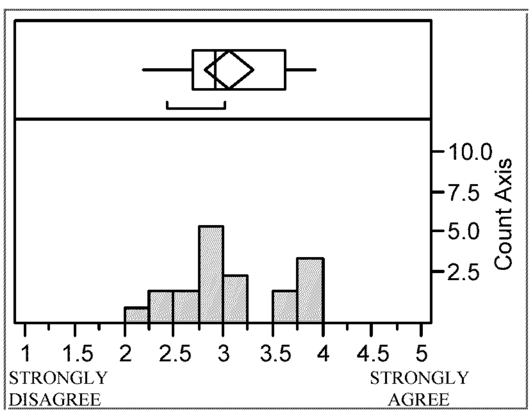
Differences on Application Modularity	F Ratio	Prob > F
IT personnel utilize object-oriented technologies to minimize the development time for new applications.	0.143	0.705
Reusable software modules are widely used in new systems development.	0.778	0.379
Legacy systems within our organization restrict the development of new applications.	0.554	0.457
End users utilize object-oriented tools to create their own applications.	0.792	0.375

Differences on Data Modularity	F Ratio	Prob > F
Mobile users have ready access to the same data used at desktops.	0.897	0.334
Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).	1.157	0.283
Data captured in one part of our organization are immediately available to everyone in the organization.	0.104	0.747
Our organization easily adapts to various vendors’ database management systems protocols and standards.	3.218	0.074

Air Force IT Infrastructure Flexibility Level

The Air Force's IT infrastructure flexibility has a score of 3.06. Calculating the mean score of each survey question and then computing the mean of those means resulted in the overall IT infrastructure flexibility score. To compute a mean score, the legacy systems question was modified to represent the majority of questions where1 indicated inflexibility and 5 indicated flexibility. The lower confidence level is 2.82. The upper confidence level is 3.31. The highest rated question on the survey was 3.92. The lowest rated question was 2.20.

Distribution of IT Infrastructure Flexibility Scores



Mean	3.067
Std Dev	0.521
Std Err Mean	0.117
upper 95% Mean	3.311
low er 95% Mean	2.822
N	20

Figure 5: Distribution of Flexibility Scores

Modularity and Integration

Modularity measures the flexibility of the data and application components of the IT infrastructure. All 8 questions measuring modularity have mean scores below 3. To compute a mean score, the legacy systems question was modified to represent the majority of questions where1 indicated inflexibility and 5 indicated flexibility. The mean modularity score is 2.66.

Integration measures the flexibility of computer platforms and communication components of the IT infrastructure. Out of 12 questions measuring integration 8 (66%) are above a score of 3. Four questions (33%) are below a score of 3. The mean value for integration is 3.36.

Combing modularity and integration provides an overall assessment of the Air Force's IT infrastructure. The diamond in Figure 6 illustrates a combined score for modularity and integration. The graph is partitioned into quadrants. The optimal combination for IT infrastructure flexibility is a high degree of modularity and integration. This is represented in the upper right hand corner. The worst quadrant is the lower left quadrant where both modularity and integration are low. The bottom right quadrant has high modularity and low integration. The upper left quadrant is high integration and low modularity.

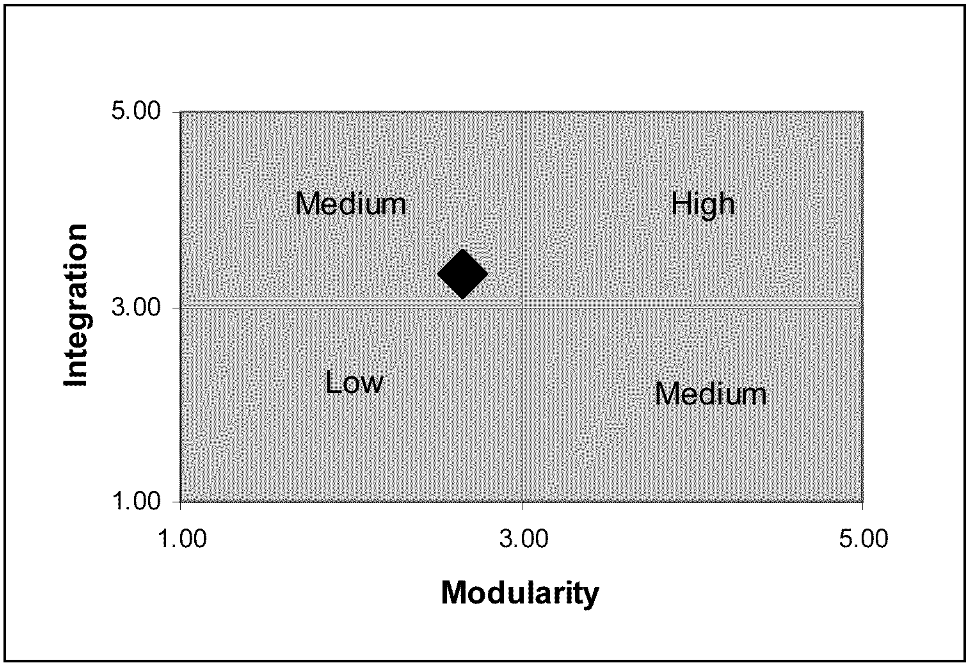


Figure 6: Air Force Flexibility Based on Modularity/Integration Mean Scores

Infrastructure Flexibility Findings

The highest level of support for IT infrastructure flexibility is within the integration construct. Subsets of integration are communications connectivity and platform compatibility. Platform compatibility has the two highest scoring questions. Seventy-four percent of respondents support that their organization utilizes common operating systems. Seventy percent of respondents agree that their organization offers a wide variety of types of information to end users. Additionally, 36 percent of respondents maintain their organizations provide multiple interfaces or entry points for external end users (e.g., Web access). The following is a list of questions that received the highest levels of support in this study.

1. Use of common operating systems (74% Agree).
2. Access to a variety of information (e.g. multimedia) (70% Agree).

3. Connectivity between remote, branch, and mobile offices to central office (66% Agree).
4. Our organization provides multiple interfaces or entry points to external end users (63% Agree).
5. Utilizing open systems network mechanisms to boost connectivity (63% Agree).

The communication connectivity category has the second highest level of support. Sixty-six percent of respondents indicated they agree that all remote, branch, and mobile offices are connected to the central office. Sixty-three percent of respondents agree that they used open system network mechanisms to boost connectivity. And sixty percent of research respondents agree that their organization has formally addressed the issue of data security with access to a number of protocols.

Only one modularity (application modularity) question received a high level of support. However, this question signifies a low level of flexibility. Fifty-five percent of respondents agree that legacy systems are restricting the development of new applications. The remaining modularity questions all have low levels of support, which indicate inflexibility. The following survey questions represent the lowest rated questions throughout the survey.

1. End users are utilizing object-oriented tools to create their own applications (15% Agree).
2. Air Force's databases do not easily adapt to various vendors' DBMS protocols and standards (18% Agree).
3. Data captured in one part of the Air Force is immediately available to everyone in the Air Force (21% Agree).
4. Legacy systems restrict development of new applications (55% Agree and 21% Disagree).
5. There are very few identifiable communications bottlenecks within our organization (24% Agree).

The question with the very lowest level of support can be found in application modularity. Only 15 percent of respondents agree that end users utilize object-oriented tools to create their own applications. Another application question with a low level of support is that 37 percent of respondents agree that reusable software modules are widely used in new systems development. And only 37 percent of respondents agree that IT personnel utilize object-oriented technologies to minimize the development time for new applications.

Low levels of support are also characteristic of data modularity. Only 18 percent of respondents agree that their organization easily adapts to various vendors' database management system protocols and standards. A mere 21 percent of respondents agree that data captured in one part of the organization are immediately available to everyone in the organization. Twenty-nine percent of respondents agree their corporate database is able to communicate through many different protocols. Thirty-two percent of respondents agree that mobile users have ready access to the same data used at desktops.

Questions measuring communication connectivity also have low levels of support. Only twenty-four percent agree that there are few identifiable communications bottlenecks within their organizations. Twenty-nine percent agree that compared to rivals, their organization has the foremost in available IT systems and connections. Forty-percent of respondents agree that their organization utilizes a virtual network or VLAN to connect to end users.

Three platform compatibility questions have low levels of support. Thirty percent of respondents agree that all remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office. Only forty-

one percent agree that their user interfaces provide transparent access to all platforms and applications. Forty-six percent of respondents agree that software applications can be easily transported and used across multiple platforms.

Summary

This chapter presented the findings of the study. The demographics findings suggest that research respondents represented many organizations and IT support positions throughout the Air Force. The IT infrastructure flexibility findings suggest a medium level of support for platform and communication flexibility. Findings also suggest a low level of respondent support for data and application modularity. The next chapter of this study is the discussion of the findings.

V. Discussion

Introduction

Based on respondents' views, the Air Force has a low level of IT infrastructure flexibility. Only seven of the twenty survey questions indicating flexibility are supported. Special attention needs to be paid to data and application modularity. None of eight questions measuring data and application modularity are supported. Of the twelve questions indicating integration only six are supported.

Discussion of Findings

The lowest rated areas of flexibility in this study center around two components of the IT infrastructure. These two components are data and applications. The very lowest rated question is that end users are not utilizing object-oriented tools to create their own applications. Some people may view this as a good sign. The Air Force has been and still is struggling with stovepiped systems that do not easily share data with other systems. Much of the blame has gone to proprietary development. This low score may represent respondents' views that development of applications by end users is no longer wanted or needed. Thus, instead of answering "not applicable," they gave it a low score. End users are typically not viewed as software developers. However, a more modern type of an object-oriented tool is GUI driven applications such as Microsoft Access. They enable development of quick and easy software applications. Nonetheless, the low

level of agreement on this question indicates a low level of flexibility. Specifically, for end users requiring novel means to exploit data and information that differs from the standard desktop or enterprise applications.

The Air Force is utilizing and developing more enterprise applications. However, the study showed application flexibility as having some of the lowest levels of flexibility. This provides evidence that the Air Force's enterprise systems do not inherently provide flexibility. Enterprise systems are at the center of the Air Force's present and future IT infrastructure. However, respondents have a low level of agreement on utilizing reusable software modules for new systems development. They also have a low level of agreement on using object-oriented tools to minimize development time for new applications. New applications without the right standards can become as stovepiped and non-interoperable as legacy systems of the past.

Fifty-five percent of respondents agree that legacy systems are still restricting the development of new applications. Older systems consisting of non-interoperable applications and database standards appear to be at least partly responsible. The majority of respondents view their organizations as unable to communicate through many different protocols. Additionally, respondents view their organization's databases as unable to adapt to other vendors' database management systems. Another low scoring data/database issue is that data captured in one part of the Air Force is not immediately available to everyone in the Air Force.

A high level example of database problems in the Air Force is the Military Personnel Data System (MilPDS). The Air Force is migrating its personnel database from a mainframe system called PCIII to MilPDS. However, the older mainframe system

"PCIII remains the single biggest obstacle to getting a 'normalized' MilPDS situation" (http://www.afpc.randolph.af.mil). This supports the idea that processes, structures, definitions, and protocols coded into old systems are restricting the Air Force's ability to share information in ways deemed valuable today. High level systems that were noted as being outdated are the following logistics and maintenance systems: Core Automated Maintenance System (CAMS), Standard Base Supply System (SBSS), Cargo Movement Operations Systems (CMOS), Weapon System Management Information System (WSMIS), Stock Control System (SCS), and the Air Force Equipment Management System (AFEMS) (Electronic Systems Command, 2001).

Results indicate the Air Force's communication connectivity is one of the high points in the Air Force's IT infrastructure. There is strong support on connectivity between remote, branch, and central offices. There is also strong support on using open system network mechanisms and taking care of network security protocols. However, results from the study also indicate that network bottlenecks are still plaguing the Air Force. The cause for communication bottlenecks may be merely an issue of bandwidth. This is suggested by the CONOPS for Air Force Information Enterprise. However, the low score may also be an indication of many other factors such as down servers, mismanagement of backups across the network, too few domain controllers, and many other issues not necessarily related to bandwidth.

Junior and Senior IT Leaders

Evidence suggests that junior and senior leaders have the same overall view of the Air Forces' IT infrastructure flexibility. Only one of the twenty questions indicates a

significant difference. That one question asks whether external end users have multiple interfaces or entry points (e.g., Web access) for access. Senior leaders rated this question significantly higher than junior leaders. A possible explanation for this difference in score could be attributed to the low number of senior IT leaders participating in the study (n=12). Another possible explanation is that high ranking officers often work in headquarters where bigger IT support organizations may provide more external connectivity in the form of web e-mail and directory access services. Additionally, higher-ranking officers may be afforded use of new and more expensive technology such as blackberries (mobile hand held e-mail computer) or other mobile personal digital assistants (PDA).

Limitations of the Research

This study is based on the views of Air Force personnel who completed the IT infrastructure flexibility survey. A limitation of this research is that these views may not indicate the true flexibility of the Air Force's IT infrastructure. A second limitation is that contactors and government service employees were excluded from the study. These two groups may have views that provide a more comprehensive or accurate assessment of the Air Force's infrastructure flexibility. A third limitation involves the low number of senior Air Force IT leaders that participated in the study. This limited the confidence in generalizing about senior IT leaders in comparisons to junior leaders. A fourth weakness of the study is that no General officers completed the survey. Generals are the most senior Air Force IT leaders and their input would have provided a more comprehensive view. Air Combat Command (ACC) is the largest Air Force MAJCOM and represented

twice as many respondents as any other Major Command in this study. This may affect the balance between MAJCOM's in depicting Air Force infrastructure flexibility. The final limitation is that the human IT infrastructure was not included. The human aspect along with the technical aspect provides the complete view of IT infrastructure flexibility.

Recommendations for Future Research

This study measured the views of Air Force personnel regarding IT infrastructure flexibility. A recommendation for future research is to use other methods to further understand the Air Force's infrastructure flexibility. This could provide further support for the current findings or produce new insight. Another area for future study is a reevaluation of the Air Force's IT infrastructure flexibility over time. Performing this study a year or two into the future will provide information about direction of the Air Force's IT infrastructure with respect to flexibility. A third area for future study is to provide modifications to the current survey. The survey was produced primarily for civilian corporations. A recommendation is to tailor the survey with more focus on the Air Force issues such as combat communications, battle management, and sensor grids to warfighter. This need was indicated by several e-mails responding to the survey.

A fourth area for future study is addressing areas within the study that indicate low levels of flexibility. A study of communication bottlenecks could provide a more thorough understanding of the particular problems users are having with bottlenecks. Are the views from respondents due to slow logins from morning network traffic, down serves, internal networks or external telecommunication lines? Hopefully this information would lead to better management practices affecting users. Views from

respondents indicate legacy systems are restricting new development. Further research could explore and identify specific legacy systems and their associated limitations. This could provide Air Force leadership information for infrastructure management. Respondents also view that Air Force's DBMS's are unable to communicate through many different DBMS's and are not adaptable to other vendors' DBMS's. Another suggestion is to explore solutions regarding the inflexible status of Air Force DBMS's. This could provide information for improving the current state of data flexibility. The study also indicates that modular programming techniques are not being utilized for software reuse. The recommendation is to further explore the use of object-oriented applications and data in the Air Force. Another area for future research is to study the human IT infrastructure. This would provide information on the flexibility of the Air Force's work force in supporting the technical IT infrastructure.

Conclusions

Research respondents supported only six of the twenty questions indicating infrastructure flexibility. This provides evidence that the Air Force's IT infrastructure flexibility is low. However, there are six areas that do indicate flexibility. Three of those areas are associated with platform compatibility. They include the use of common operating systems, access to a variety of information types, and multiple entry points for external end users. The first recommendation is to ensure the continued success of platform standards in directing the use of common operating systems. This area is one of the highest rated areas of the study. This provides evidence that the Air Force's platforms are compatible. However, there is also evidence of incompatibility. An

indication of incompatibility is found in the low transportability of applications and platform transparency. A recommendation is for the Air Force to continue developing web-based enterprise systems with the right mix of standards to span the Air Force. Access to such systems only requires a web browser. Platform transparency and application transparency can be increased with worldwide access through web technology.

Respondents believe that the Air Force has good communication connectivity between remote, branch, and mobile offices. They also indicate a high level of agreement on the Air Force's use of open network standards and data security protocols. However, even higher levels of agreement are restricted by communication bottlenecks. This may strictly be a bandwidth issue. However problems may result from other issues such as too few domain controllers, down servers, mismanagement of backups, mismanagement of network configurations or other factors. The recommendation is to further focus and analyze the problems causing communication bottlenecks.

The results from this study suggest that the inflexibility of the Air Force's data is a major limiting factor to its infrastructure flexibility. The Air Force is trying to better manage its data by server consolidation. A recommendation is to continue to focus on Air Force server consolidation. This is an opportunity for the Air Force to improve data modularity through the variety and adaptability of its database protocols. This can also be an opportunity to improve the Air Force's ability to immediately share data between coordinating organizations. Nonetheless, none of the data flexibility questions were supported and this suggests that much attention and work is needed to improve this vital area.

Lack of application modularity is shown as the second major limitation to the Air Force's IT infrastructure flexibility. Findings suggest that legacy systems are restricting new development. Results also suggest that organizations are not using object-oriented tools for new software development. Another finding is that modular programming techniques are not being utilized for software reuse. The recommendation is to further explore the use of object-oriented applications and data in the Air Force.

Appendix A: IT Infrastructure Flexibility Survey

Air Force IT Infrastructure Flexibility Survey

Welcome to the Air Force Information Technology (IT) Infrastructure Flexibility Survey. Please take the next few minutes to answer the following series of questions concerning the flexibility of YOUR organization's UNCLASSIFIED IT infrastructure (i.e. the organization you are currently supporting, base, MAJCOM HQ, etc.).

Please enter the following demographic information:

Your job title is: [ ], At what level: [Executive ▾]

Organizational level: [Air Staff ▾]
Rank: [MSGT ▾]
MAJCOM: [ACC ▾]
AFSC: [33S ▾]
Gender: Male: ◉ Female: ○

Years of experience in IT: [ ]
How many people does your organization support? [ ]
Please indicate the highest level of education you have completed: [High School Degree ▾]

PLEASE RATE THE STATEMENTS BELOW FROM (1) STRONGLY DISAGREE TO (5) STRONGLY AGREE.

The questions below relate to <u>IT Connectivity</u> within your organization.

	STRONGLY DISAGREE 1	2	3	4	STRONGLY AGREE 5	N/A
1. Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).	○	○	○	○	○	○
2. Flexible electronic links exist between our organization and external entities (e.g., vendor, customers). (Flexible links are where nodes are able to be added, deleted, available, and modified as needs dictate)	○	○	○	○	○	○
3. Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).	○	○	○	○	○	○
4. All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing data and processing).	○	○	○	○	○	○
5. Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI).	○	○	○	○	○	○
6. There are very few identifiable communications bottlenecks within our organization.	○	○	○	○	○	○
7. Our organization utilizes a virtual network or VLAN to connect to end users. (A virtual network or VLAN is a local area network with a definition that maps workstations on some other basis than geographic location (for example, by department, type of user, or primary application). The virtual LAN controller can change or add workstations and manage load balancing and bandwidth allocation more easily than with a physical picture of the LAN. Network management software keeps track of relating the virtual picture of the local area network with the actual physical picture. (www.whatis.com)	○	○	○	○	○	○
8. New locations or acquisitions are quickly assimilated into our IT infrastructure.	○	○	○	○	○	○

The questions below relate to <u>Application Functionality</u> within your organization.

	STRONGLY DISAGREE 1	2	3	4	STRONGLY AGREE 5	N/A
1. The applications used in our organization are designed to be reusable.	○	○	○	○	○	○
2. Reusable software modules are widely used in new systems development. (Reusable meaning the ability to utilize software modules built in one application into another)	○	○	○	○	○	○
3. End users utilize object-oriented tools to create their own applications.	○	○	○	○	○	○
4. IT personnel utilize object-oriented technologies to minimize the development time for new applications.	○	○	○	○	○	○
5. Legacy systems within our organization restrict the development of new applications.	○	○	○	○	○	○
6. Data processing (e.g., batch job, key entry time, etc.) does NOT restrict normal business operations or functions.	○	○	○	○	○	○
7. We have a backlog of IT design work for new applications.	○	○	○	○	○	○
8. Our organization uses enterprise-wide application software.	○	○	○	○	○	○

The questions below relate to IT Compatibility within your organization.

	STRONGLY DISAGREE 1	2	3	4	STRONGLY AGREE 5	N/A
1. Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office (i.e. ability to access data wherever an office is located without having to perform more procedures than would take from home office).	○	○	○	○	○	○
2. End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).	○	○	○	○	○	○
3. Software applications can be easily transported and used across multiple platforms.	○	○	○	○	○	○
4. Our organization offers a wide variety of types of information to end users (e.g., multimedia).	○	○	○	○	○	○
5. Our user interfaces provide transparent access to all platforms and applications.	○	○	○	○	○	○
6. Data received by our organization from electronic links (e.g., EDI, EFT) are easily interpretable.	○	○	○	○	○	○
7. The rapidity of IT change (e.g., revision level, release) in our organization is high.	○	○	○	○	○	○
8. Information is shared seamlessly across our organization, regardless of the location.	○	○	○	○	○	○
9. Our organization provides multiple interfaces or entry points (e.g., Web access for external end users)	○	○	○	○	○	○

The questions below relate to Data Transparency within your organization.

	STRONGLY DISAGREE 1	2	3	4	STRONGLY AGREE 5	N/A
1. Our organization utilizes online analytical processing (OLAP). (OLAP provides executives, analysts and managers with valuable information via a " slice, dice and rotate" method of end user data access, augmenting or replacing the more complicated relational query)	○	○	○	○	○	○
2. Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).	○	○	○	○	○	○
3. Mobile users have ready access to the same data used at desktops.	○	○	○	○	○	○
4. A common view of our organization's customer is available to everyone in the organization.	○	○	○	○	○	○
5. Our organization easily adapts to various vendors' database management systems protocols and standards.	○	○	○	○	○	○
6. Data captured in one part of our organization are immediately available to everyone in the organization.	○	○	○	○	○	○
7. Our IT organization handles variances in corporate data formats and standards.	○	○	○	○	○	○
8. Data rules and relations (e.g., tax regulations) are hard-coded into applications.	○	○	○	○	○	○

Submit Answers

Appendix B: E-mail Sent to Research Subjects

Air Force Communications-Computer Systems Professional:

You have been selected to participate in a study conducted by researchers at the Air Force Institute of Technology, Wright-Patterson AFB, OH. The purpose of this study is to assess Information Technology (IT) Infrastructure Flexibility within the Air Force. This study has been distributed to information technology (IT) support professionals who are experienced and knowledgeable to answer topics pertaining to IT infrastructures. Your input to this study is very valuable and may help to influence the future of the Air Force's IT infrastructure. Please answer the survey questions based on your current organization's IT infrastructure (i.e. base, MAJCOM HQ, Air Force-wide, etc.).

This study has been approved by the HQ AFPC Survey Branch and assigned an Air Force Survey Control Number of USAF SCN 01-114.

This survey was developed for IT executives in the commercial sector. Additionally the survey instrument has been tested and validated. The questions asked may not necessarily be related to your current mission in the Air Force, but please answer the questions to the best of your ability.

Please go to the web site listed below and complete the survey at your earliest convenience.

<<http://en.afit.edu/env/itflexibility/default.asp>>
Thank you in advance for your participation in this study.

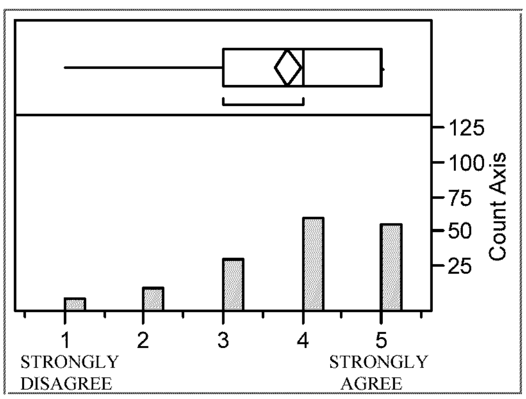
Appendix C: Infrastructure Flexibility Distribution Graphs

Integration: Network/Telecom Connectivity

Integration Questions 1: All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing and processing data).

The modal score (34%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 130 (66%) of 194 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 26 (14%) of the ratings. Thirty-eight respondents (20%) selected 3 showing neither agreement nor disagreement. The mean score was 3.81. An illustration of the distribution and related statistics can be seen in Figure 13.

Integration Question 1: All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing and processing data).



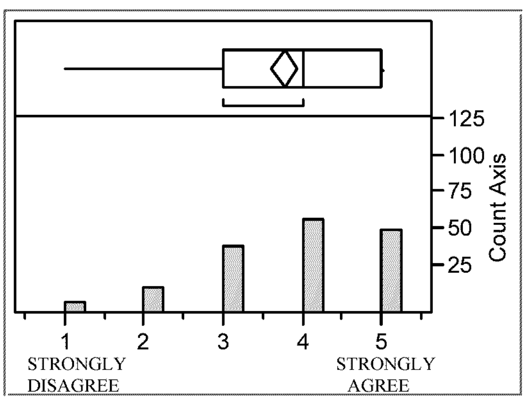
Mean	3.814
Std Dev	1.123
N	194
N/A or Left Blank	22

Figure 7: Respondent Distributions on Remote, Branch, and Mobile Connectivity

Integration Question 2: Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI).

The modal score (36%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 118 (60%) of 189 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 27 (14%) of the ratings. Fifty respondents (26%) selected 3 showing neither agreement nor disagreement. The mean score was 3.77. An illustration of the distribution and related statistics can be seen in Figure 14.

Integration Question 2: Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI).



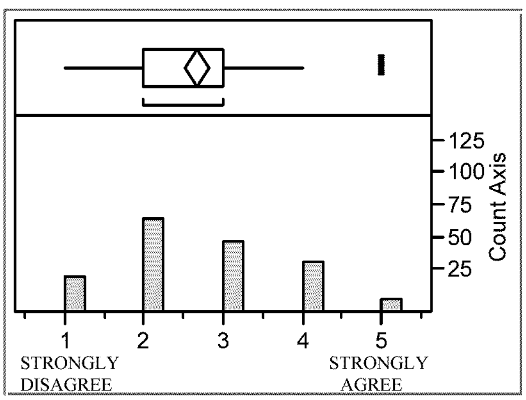
Mean	3.772
Std Dev	1.090
N	189
N/A or Left Blank	27

Figure 8: Respondent Distributions on Open System Network Mechanisms

Integration Question 3: There are very few identifiable communications bottlenecks within our organization.

The modal score (35%) was 2. Respondents selected 1 (strongly disagree) or 2 (disagree) in 100 (49%) of 205 rating submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 50 (24%) of the ratings. Fifty-five respondents (27%) selected 3 showing neither agreement nor disagreement. The mean score was 2.67. An illustration of the distribution and related statistics can be seen in Figure 15.

Integration Question 3: There are very few identifiable communications bottlenecks within our organization.



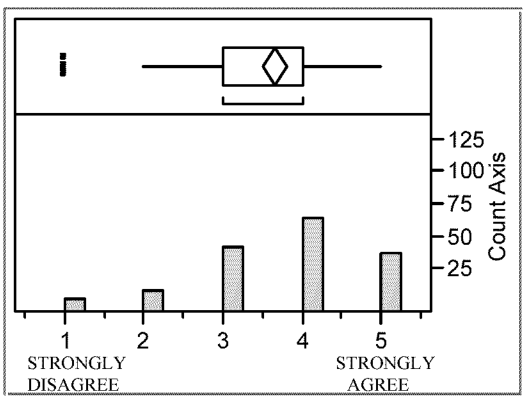
Mean	2.673
Std Dev	1.096
N	205
N/A or Left Blank	11

Figure 9: Respondent Distributions on Communication Bottlenecks

Integration Question 4: Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).

The modal score (36%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 118 (60%) of 195 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 27 (14%) of the ratings. Fifty respondents (26%) selected 3 showing neither agreement nor disagreement. The mean score was 3.65. An illustration of the distribution and related statistics can be seen in Figure 16.

Integration Question 4: Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).



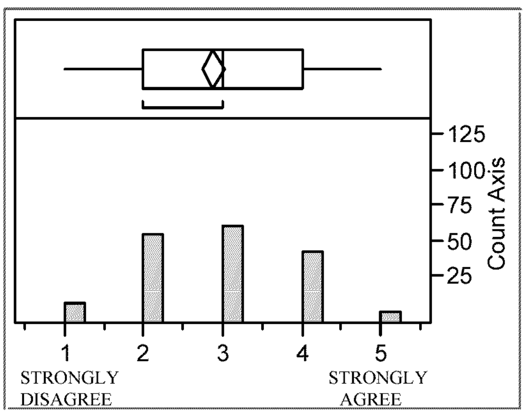
Mean	3.651
Std Dev	1.090
N	195
N/A or Left Blank	21

Figure 10: Respondent Distributions on Security Protocols

Integration Question 5: Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).

The modal score (34%) was 3. Respondents selected 1 (strongly disagree) or 2 (disagree) in 77 (37%) of 204 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 59 (29%) of the ratings. The mean score was 2.87. An illustration of the distribution and related statistics can be seen in Figure 17.

Integration Question 5: Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).



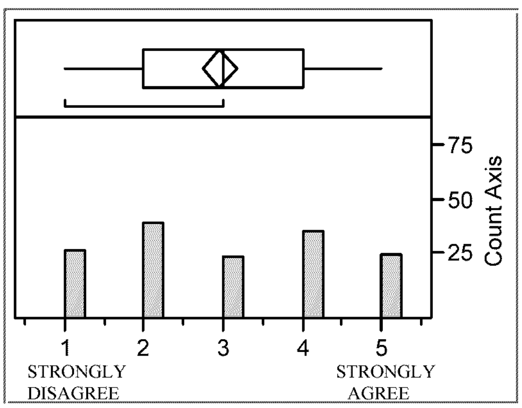
Mean	2.877
Std Dev	0.997
N	204
N/A or Left Blank	12

Figure 11: Respondent Distributions on Foremost in Connectivity

<u>Integration Question 6</u>: Our organization utilizes a virtual network or VLAN to connect to end-users.

The modal score (26%) was 2. Respondents selected 1 (strongly disagree) or 2 (disagree) in 76 (44%) of 176 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 71 (40%) of the ratings. Twenty-nine respondents (16%) selected 3 showing neither agreement nor disagreement. The mean score was 2.96. An illustration of the distribution and related statistics can be seen in Figure 18.

Integration Question 6: Our organization utilizes a virtual network or VLAN to connect to end-users.



Mean	2.960
Std Dev	1.379
N	176
N/A or Left Blank	40

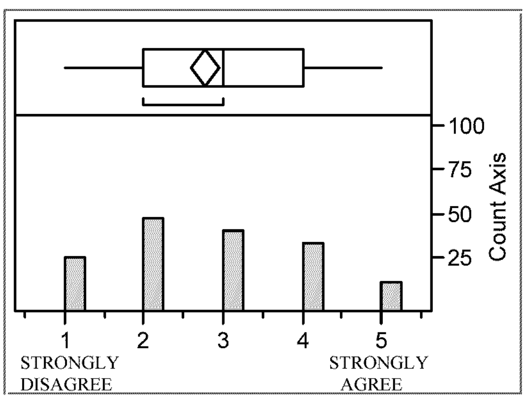
Figure 12: Respondent Distributions on Virtual LAN

Integration: Platform Compatibility

Integration Question 7: Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office.

The modal score (29%) was 2. Respondents selected 1 (strongly disagree) or 2 (disagree) in 84 (45%) of 188 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 57 (30%) of the ratings. Forty-seven respondents (25%) selected 3 showing neither agreement nor disagreement. The mean score was 2.78. An illustration of the distribution and related statistics can be seen in Figure 19.

Integration Question 7: Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office.



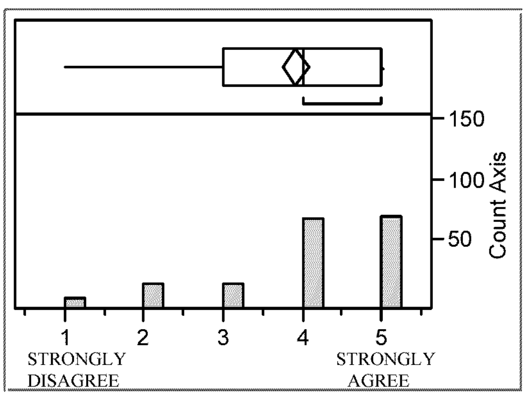
Mean	2.782
Std Dev	1.215
N	188
N/A or Left Blank	28

Figure 13: Respondent Distributions on Additional Steps to Access Data

Integration Question 8: End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).

The modal score (37%) was 5. Respondents selected 4 (agree) or 5 (strongly agree) in 153 (74%) of 206 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 31 (15%) of the ratings. Twenty-two respondents (11%) selected 3 showing neither agreement nor disagreement. The mean score was 3.91. An illustration of the distribution and related statistics can be seen in Figure 20.

Integration Question 8: End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).



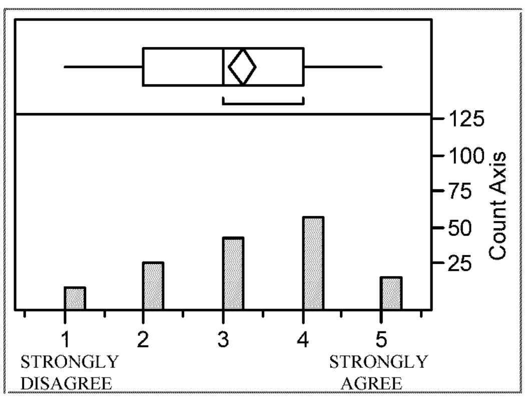
Mean	3.917
Std Dev	1.151
N	206
N/A or Left Blank	10

Figure 14: Respondent Distributions on Common Operating Systems

Integration Question 9: Software applications can be easily transported and used across multiple platforms.

The modal score (33%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 88 (46%) of 188 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 50 (27%) of the ratings. Fifty respondents (27%) selected 3 showing neither agreement nor disagreement. The mean score was 3.24. An illustration of the distribution and related statistics can be seen in Figure 21.

Integration Question 9: Software applications can be easily transported and used across multiple platforms.



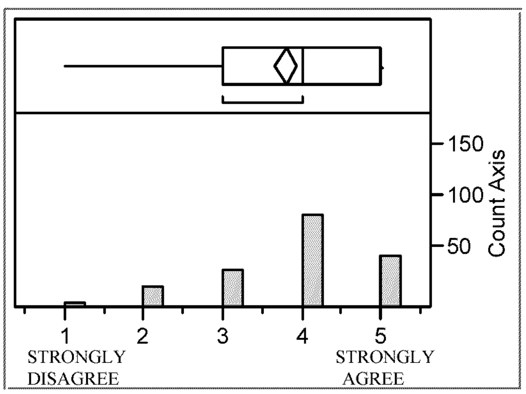
Mean	3.245
Std Dev	1.149
N	188
N/A or Left Blank	28

Figure 15: Respondent Distributions on Transportability of Applications

Integration Question 10: Our organization offers a wide variety of types of information to end users (e.g., multimedia).

The modal score (45%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 141 (70%) of 202 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 25 (12%) of the ratings. Thirty-six respondents (18%) selected 3 showing neither agreement nor disagreement. The mean score was 3.80. An illustration of the distribution and related statistics can be seen in Figure 22.

Integration Question 10: Our organization offers a wide variety of types of information to end users (e.g., multimedia).



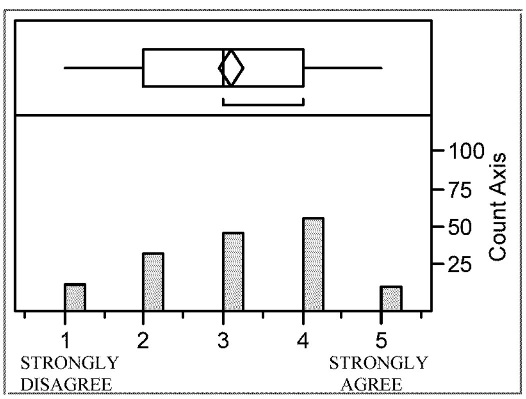
Mean	3.802
Std Dev	1.008
N	202
N/A or Left Blank	14

Figure 16: Respondent Distributions on Types of Information

Integration Question 11: Our user interfaces provide transparent access to all platforms and applications.

The modal score (32%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 79 (41%) of 190 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 58 (31%) of the ratings. Fifty-three respondents (28%) selected 3 showing neither agreement nor disagreement. The mean score was 3.10. An illustration of the distribution and related statistics can be seen in Figure 23.

Integration Question 11: Our user interfaces provide transparent access to all platforms and applications.



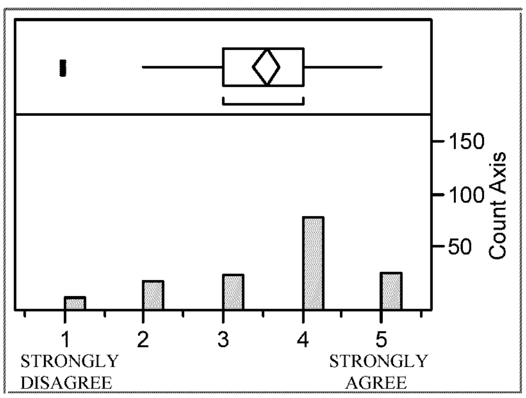
Mean	3.100
Std Dev	1.134
N	190
N/A or Left Blank	26

Figure 17: Respondent Distributions on Interfaces Providing Transparent Access

Integration Question 12: Our organization provides multiple interfaces or entry points (e.g., Web access for external end users).

The modal score (45%) was 4. Respondents selected 4 (agree) or 5 (strongly agree) in 114 (63%) of 198 ratings submitted. Respondents selected 1 (strongly disagree) or 2 (disagree) in 40 (20%) of the ratings. Thirty-four respondents (17%) selected 3 showing neither agreement nor disagreement. The mean score was 3.54. An illustration of the distribution and related statistics can be seen in Figure 24.

Integration Question 12: Our organization provides multiple interfaces or entry points (e.g., Web access) for external end users.



Mean	3.545
Std Dev	1.124
N	198
N/A or Left Blank	18

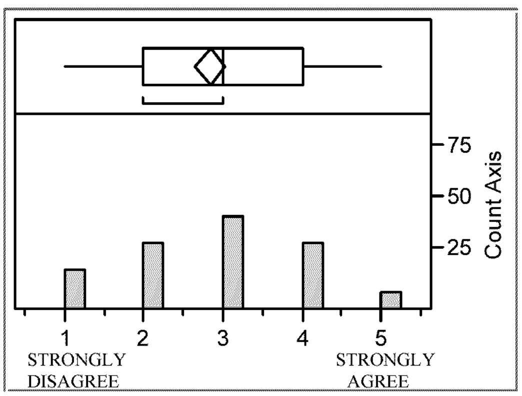
Figure 18: Respondent Distributions on Interfaces for External End Users

Application Modularity

Modularity Question 1: Reusable software modules are widely used in new systems development.

The modal score has a tie at the 2 and 4 ratings (24% each). Respondents selected 1 (strongly disagree) or 2 (disagree) in 51 (38%) of 136 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 40 (30%) of the ratings. Forty-five respondents (32%) selected 3 showing neither agreement nor disagreement. The mean score was 2.83. An illustration of the distribution and related statistics can be seen in Figure 25.

Modularity Question 1: Reusable software modules are widely used in new systems development.



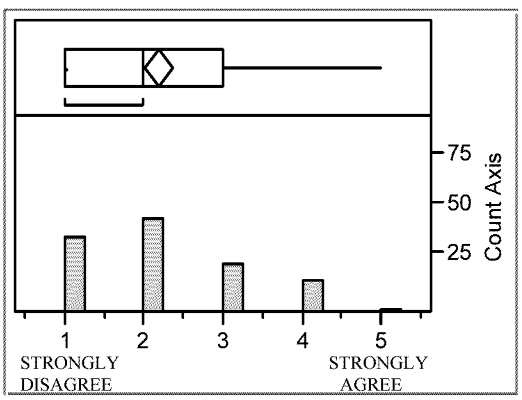
Mean	2.838
Std Dev	1.117
N	136
N/A or Left Blank	80

Figure 19: Respondent Distributions on Reusable Software Modules

<u>Modularity Question 2</u>: End users utilize object-oriented tools to create their own applications.

The modal score (36%) was 2. Respondents selected 1 (strongly disagree) or 2 (disagree) in 85 (65%) of 128 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 18 (15%) of the ratings. Twenty-five respondents (20%) selected 3 showing neither agreement nor disagreement. The mean score was 2.19. An illustration of the distribution and related statistics can be seen in Figure 26.

Modularity Question 2: End users utilize object-oriented tools to create their own applications.



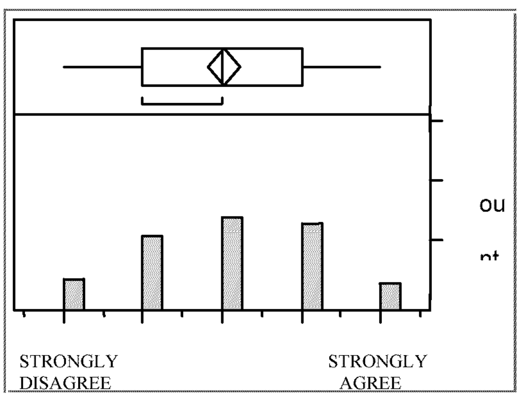
Mean	2.195
Std Dev	1.050
N	128
N/A or Left Blank	88

Figure 20: Respondent Distributions on End Users and Object-Oriented Tools

<u>Modularity Question 3</u>: IT personnel utilize object-oriented technologies to minimize the development time for new applications.

The modal score (29%) was 3. Respondents selected 1 (strongly disagree) or 2 (disagree) in 45 (34%) of 133 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 49 (37%) of the ratings. The mean score was 3.02. An illustration of the distribution and related statistics can be seen in Figure 27.

Modularity Question 3: IT personnel utilize object-oriented technologies to minimize the development time for new applications.



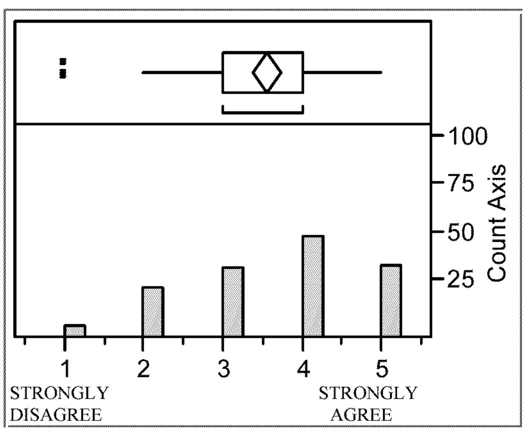
Mean	3.023
Std Dev	1.131
N	133
N/A or Left Blank	83

Figure 21: Respondent Distributions on Utilizing OO Tools to Save Time

Modularity Question 4: Legacy systems within our organization restrict the development of new applications.

The modal score (32%) was 4 (Agree). Respondents selected 4 (Agree) or 5 (Strongly Agree) in 91 (56%) of 161 ratings submitted. Respondents selected 1 (Strongly Disagree) or 2 (Disagree) in 33 (21%) of the ratings. Thirty-seven respondents (23%) selected 3 showing neither agreement nor disagreement. The mean score was 3.55. An illustration of the distribution and related statistics can be seen in Figure 28.

Modularity Question 4: Legacy systems within our organization restrict the development of new applications.



Mean	3.559
Std Dev	1.134
N	161
N/A or Left Blank	55

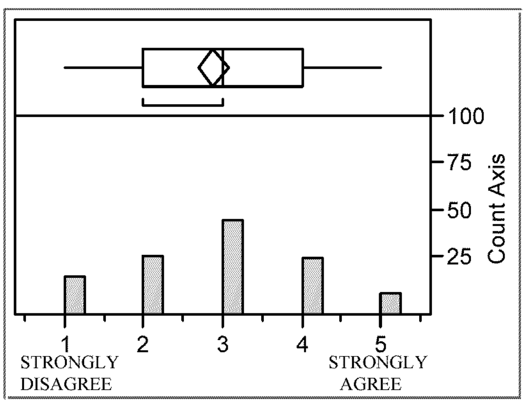
Figure 22: Respondent Distributions on Legacy Systems

Data Modularity

Modularity Question 5: Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).

The modal score (35%) was 3. Respondents selected 1 (strongly disagree) or 2 (disagree) in 52 (36%) of 145 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 43 (29%) of the ratings. The mean score was 2.88. An illustration of the distribution and related statistics can be seen in Figure 29.

Modularity Question 5: Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).



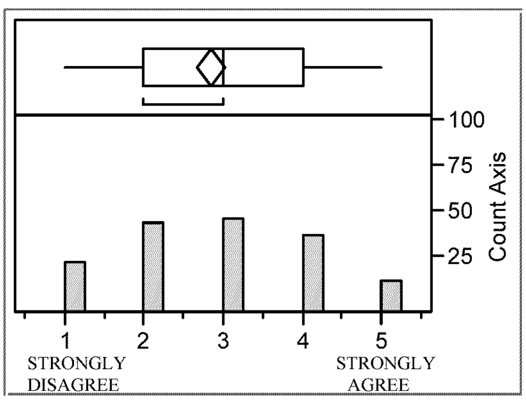
Mean	2.883
Std Dev	1.146
N	145
N/A or Left Blank	71

Figure 23: Respondent Distributions on Communicating through Many DB Protocols

Modularity Question 6: Mobile users have ready access to the same data used at desktops.

The modal score (27%) was 3. Respondents selected 1 (strongly disagree) or 2 (disagree) in 77 (41%) of 188 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 60 (32%) of the ratings. The mean score was 2.85. An illustration of the distribution and related statistics can be seen in Figure 30.

Modularity Question 6: Mobile users have ready access to the same data used at desktops.



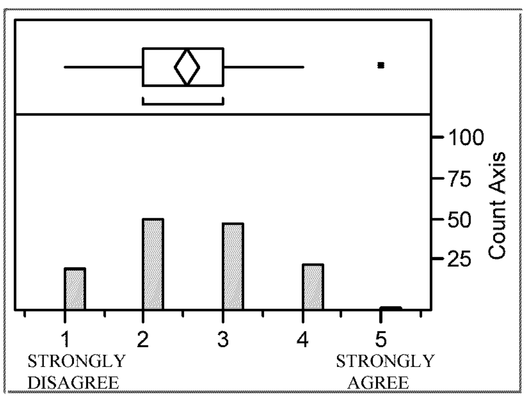
Mean	2.851
Std Dev	1.197
N	188
N/A or Left Blank	28

Figure 24: Respondent Distributions on Mobile Access Same as Desktops

Modularity Question 7: Our organization easily adapts to various vendors' database management systems protocols and standards.

The modal score (34%) was 2. Respondents selected 1 (strongly disagree) or 2 (disagree) in 83 (50%) of 167 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 30 (18%) of the ratings. Fifty-four respondents (32%) selected 3 showing neither agreement nor disagreement. The mean score was 2.53. An illustration of the distribution and related statistics can be seen in Figure 31.

Modularity Question 7: Our organization easily adapts to various vendors' database management systems protocols and standards.



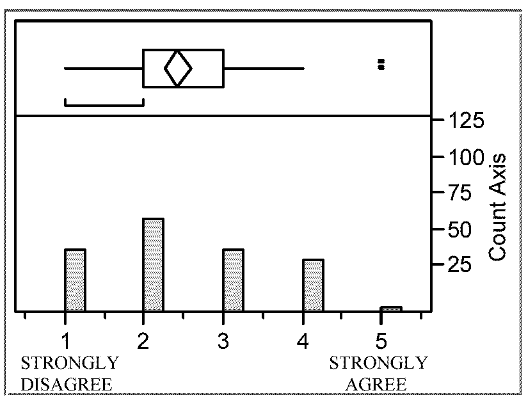
Mean	2.539
Std Dev	0.986
N	167
N/A or Left Blank	49

Figure 25: Respondent Distributions on Database Adaptability to DBMS Protocols

Modularity Question 8: Data captured in one part of our organization are immediately available to everyone in the organization.

The modal score (33%) was 2. Respondents selected 1 (strongly disagree) or 2 (disagree) in 107 (56%) of 190 ratings submitted. Respondents selected 4 (agree) or 5 (strongly agree) in 39 (21%) of the ratings. Forty-four respondents (23%) selected 3 showing neither agreement nor disagreement. The mean score was 2.43. An illustration of the distribution and related statistics can be seen in Figure 32.

Modularity Question 8: Data captured in one part of our organization are immediately available to everyone in the organization.



Mean	2.432
Std Dev	1.085
N	190
N/A or Left Blank	26

Figure 26: Respondent Distributions on Sharing Data

Appendix D: Relevance of Survey Questions to Infrastructure Flexibility

The following is a list of questions in Byrd et al's survey. A sentence or two is included to explain how each question is relevant to flexibility. These questions will be asked of Air Force IT support professionals to measure their views on the Air Force's IT infrastructure flexibility.

A. Integration survey questions with respect to network/telecommunications connectivity:

1. Our organization utilizes open systems network mechanisms to boost connectivity (e.g., ATM, FDDI). (Open system network mechanisms are technologies based on standards that are developed to enable connectivity with other network technologies).
   - Open system network mechanisms provide fast and flexible transmission of data.

2. There are very few identifiable communications bottlenecks within our organization.
   - The more problems with bottlenecks the less connected and flexible an organization.

3. Compared to rivals within our industry, our organization has the foremost in available IT systems and connections (e.g., ADSL, VDSL, AFM, SDV).
   - More capable and advanced network/telecom connections tend to support more flexible network capabilities.

4. Our organization has formally addressed the issue of data security with access to a number of protocols (e.g., Kerberos V.5, MIME, PGP, S-HTTP).
   - Security of information is an important factor for flexible information sharing.

5. All remote, branch, and mobile offices are connected to the central office (i.e. have electronic connection for sharing data and processing).
   - This provides the flexibility to exchange data and information wherever an office may be located.

6. Our organization utilizes a virtual network or VLAN to connect to end users. (A virtual network or VLAN is a local area network with a definition that maps workstations on some other basis than geographic location (for example, by department, type of user, or primary application). The virtual LAN controller can

change or add workstations and manage load balancing and bandwidth allocation more easily than with a physical picture of the LAN. Network management software keeps track of relating the virtual picture of the local area network with the actual physical picture. (www.whatis.com)

- This provides the flexibility to add, delete, or move users throughout the network in less time and work.

B. Integration survey questions with respect to platform compatibility:

1. Remote, branch, and mobile offices do not have to perform any additional steps or procedures to access data from home or central office (i.e. ability to access data wherever an office is located without having to perform more procedures than would take from home office).
    - Additional steps restrict the time and complexity in accessing data. This restriction causes inflexibility. Automated procedures for accessing data enable flexibility.

2. End users throughout the organization utilize a common operating system (e.g., UNIX, OS/2).
    - Common operating systems result in compatible platforms that are not hampered by inflexible platforms.

3. Software applications can be easily transported and used across multiple platforms.
    - The ability to transport applications enables the flexibility to share applications wherever needed.

4. Our organization offers a wide variety of types of information to end users (e.g., multimedia).
    - The more types of information, the more flexibility in utilizing any information required.

5. Our user interfaces provide transparent access to all platforms and applications.
    - Transparent access provides flexibility by providing fast and easy access to information resources.

6. Our organization provides multiple interfaces or entry points (e.g., Web access for external end users).
    - Multiple entry points enable the flexibility to access data and information from different locations.

C. Modularity survey questions with respect to applications:

1. Reusable software modules are widely used in new systems development. (Reusable is the ability to utilize software modules built in one application by other applications)
    - Reusable software provides flexibility and efficiency by utilizing existing software.

2. End users utilize object-oriented tools to create their own applications. Object-oriented technology by definition is modular.
    - This enables end users the flexibility to exploit data in new and novel ways without having to coordinate changes through other people and processes.

3. IT personnel utilize object-oriented technologies to minimize the development time for new applications.
    - Using object-oriented technologies to minimize development time results in a faster more modular and flexible IT infrastructure.

4. Legacy systems within our organization restrict the development of new applications.
    - Legacy systems that restrict new development do not provide the component-based structure and flexibility newer modular systems provide.

D. Modularity survey questions with respect to data:

1. Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC).
    - The more protocols through which databases are able to communicate, the more flexible they will be in sharing data to systems using different protocols.

2. Mobile users have ready access to the same data used at desktops.
    - Mobile access to data increases the location flexibility of the system.

3. Our organization easily adapts to various vendors' database management systems protocols and standards.
    - Adapting to other database management system's protocols enables the flexibility to interoperate with other systems.

4. Data captured in one part of our organization are immediately available to everyone in the organization.
    - This provides the flexibility to share and exploit data quickly.

Appendix E: Executive Summary

The Air Force presently spends more than $4.9 billion annually on information technology (IT). However, the IT infrastructure has been identified as inappropriate for supporting the Air Force mission. To improve this situation the Air Force has identified infrastructure flexibility as key to future success. This led to the thesis question: What is the Air Force's current level of IT infrastructure flexibility?

The thesis looked at four constructs that indicate IT infrastructure flexibility—modularity (data modularity, application modularity), and integration (communication connectivity, and platform compatibility). A survey was sent to 1,000 communication, computer, and information professionals (33SX and 3COX2 career fields) from around the Air Force to measure these constructs. Based on results from 216 responses, the Air Force's IT infrastructure does have some areas of flexibility, but other areas indicate very low flexibility. A primary concern is the flexibility of the Air Force's data and applications. Responses to both data flexibility and application flexibility questions rated consistently low. The responses suggest the Air Force could achieve greater flexibility by turning its attention to database issues such as variety and adaptability of database protocols. In addition, application development practices such as module reuse, and using object-oriented development technologies could provide further flexibility to the Air Force's applications.

Flexibility of Air Force communications and platforms is partially supported. Results indicate that communication bottlenecks are still causing problems across the Air

Force. However, communication flexibility is found in the following areas: addressing security protocols, using the latest network and telecommunication technologies, and having connections between remote, branch, and mobile offices to central offices. Furthermore, computer platforms are being standardized on commercial products, and processing a wide variety of information such as multimedia. Additionally, organizations are providing access to external end users through such means as Web access.

The average scores of modularity and integration questions are represented by the diamond in Figure 27. The questions were based on a 5-point likert scale with 1 indicating inflexibility, up to 5 five, which indicates flexibility.

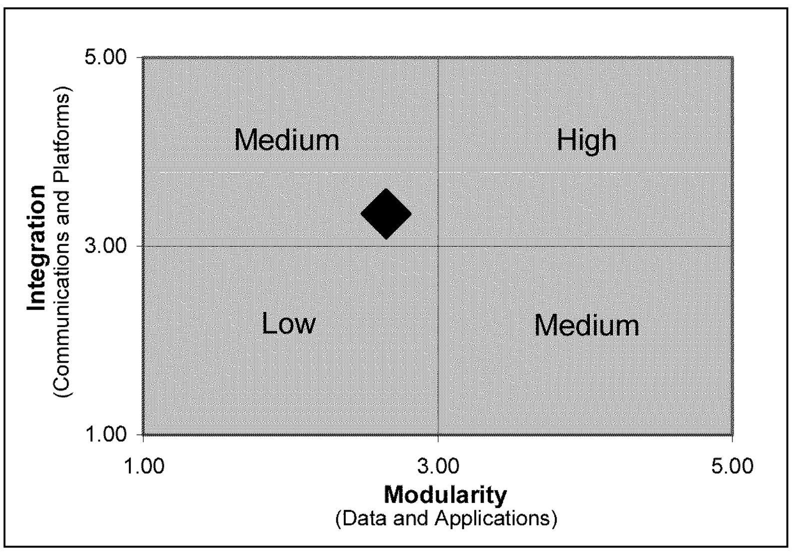


Figure 27: Air Force Flexibility Based on Modularity/Integration Mean Scores

Results indicate that Air Force communications and computer platforms (integration) are more flexible than the data and application (modularity) components. A possible explanation is the more daunting task of managing, standardizing, and coordinating databases and software applications. Whereas, the higher level of flexibility

seen in Air Force computer platforms may be an effect of computer hardware standards as well as industry standards such as Microsoft products. Additionally, telecommunications lines are simply being plugged into, and internal Air Force network technologies are being kept up to date. Thus, computer platforms and networks/telecommunications are already somewhat flexible. This suggests the Air Force turn its focus to invest and improve data and application architectures.

Analysis between senior IT leaders and junior IT leaders on Air Force IT infrastructure flexibility resulted in no overall significant differences. The only area where they differed was on the number of entry points or interfaces available to external end users. This phenomenon may be attributed to the privileged access of senior leaders to new technologies such as Blackberries and other Personal Digital Assistants (PDA). This purpose of this study is to provide a picture of the Air Force's IT infrastructure flexibility. Hopefully, these findings will help Air Force planners build more flexible and adequate IT infrastructures in support of Aerospace operations.

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Vita

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14. ABSTRACT

The Air Force presently spends more than $4.9 billion annually on information technology (IT). However, the IT infrastructure has been identified as inappropriate for supporting the Air Force mission. To improve this situation the Air Force has identified infrastructure flexibility as key to future success. This led to the thesis question: What is the Air Force's current level of IT infrastructure flexibility?

This thesis looked at two constructs that indicate IT infrastructure flexibility—modularity and integration. A survey was sent to communication, computer, and information career field members to measure the degree of modularity and integration. Based on respondents' views, the Air Force's IT infrastructure does have some areas of flexibility, but other areas indicate very low flexibility. A primary concern is the flexibility of the Air Force's data and applications. Responses to both data flexibility and application flexibility survey questions consistently indicated low flexibility. The responses suggest the Air Force could achieve greater flexibility by turning its attention to database issues such as variety and adaptability of database protocols. Communications and platform flexibility are partially supported. Results indicate that reducing communication bottlenecks and fewer steps for accessing data from external end user locations could enable greater flexibility. Senior and junior IT leaders only diverged on one area of flexibility. Senior leaders had a higher rating on the number of entry points or interfaces available to external end users.

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